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Cost Estimating Manual - Combined Sewer Overflow Storage and Treatment

Culp, Wesner, Culp - Clean Water Consultants, Eldorado Hills, CA

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16. ABSTRACT

Data for estimating average construction costs and operation and maintenance requirements are presented for combined sewer overflow treatment plants ranging from 5 to 200 million gallons per day in capacity, and storage facilities ranging in size from 1 to 240 million gallons. Estimating data are included for 14 separate process functions associated with stormwater treatment plants and storage facilities. An example of the use of the data is given.

Estimated average construction costs and operation and maintenance requirements are related graphically to appropriate single parameters for respective plant components. In addition, cost components of the process functions are presented to enable inflating cost-related materials and wages.

The data presented provides means of estimating costs and operating and maintenance requirements for a variety of facilities on an average basis, but do not supplant the need for detailed study of local conditions or recognition of changing design requirements in preparing estimates for specific applications.

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COST ESTIMATING MANUAL -- COMBINED SEWER OVERFLOW STORAGE AND TREATMENT

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report presents data from which construction costs and operating and maintenance requirements may be estimated for combined sewer overflow treatment and storage facilities. The use of the information contained in this report facilitates making cost analyses for alternative solutions to proposed projects.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

ABSTRACT

Data for estimating average construction costs and operation and maintenance requirements are presented for combined sewer overflow treatment plants ranging from about 5 to 200 million gallons per day in capacity, and storage facilities ranging in size from 1 to 240 million gallons. Estimating data are included for 14 separate process functions associated with stormwater treatment plants and storage facilities. An example of the use of the data is given.

Estimated average construction costs and operation and maintenance requirements are related graphically to appropriate single parameters for respective plant components. In addition, cost components of the process functions are presented to enable inflating cost-related materials and wages.

The data presented provides means of estimating costs and operating and maintenance requirements for a variety of facilities on an average basis, but do not supplant the need for detailed study of local conditions or recognition of changing design requirements in preparing estimates for specific applications.

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SECTION I

INTRODUCTION

The planning for projects for the treatment of wastewaters inherently requires an analysis of capital and operating and maintenance costs. Capital costs include construction costs, engineering, legal, administrative, land, and interest during construction. The emphasis of this report is placed on developing construction costs. Other costs, except land, may be related to construction costs. Land is a variable which cannot be typified. General information for plant construction costs has been available; however, this information is often presented for an overall process rather than in terms of unit processes. The variability of combinations of several unit processes makes usage of historical data limited. By separating plant costs into categories of unit processes, historical cost data from one plant may be applied to similar processes for the plant being planned.

This approach to estimating project construction costs is a time honored method used by most engineers in the utility field. Until recently, however, the information for wastewater unit process costs was unorganized and generally inaccessible. The first significant attempt to collect and correlate unit process cost data was presented in a U.S. Environmental Protection Agency Report(1). In addition to providing construction costs for unit processes, the report also presented labor and material and supply costs for conventional unit processes.

The widespread use of the information presented in that report reflects the value of unit process costing information. Also much of the information presented in that report is used in the EPA's executive program for costs and operating requirements of wastewater treatment.

A. PURPOSE

It is the purpose of this report to develop construction cost information and operating and maintenance requirements for unit processes applicable to combined sewer overflow treatment and storage facilities. Functional processes investigated include the following:

Swirl Flow Regulator/Concentrator
Stationary Screens
Horizontal Shaft Rotary Screen
Vertical Shaft Rotary Screen
Air Flotation
Chlorination
Granular Media Filtration
Storage
Flocculation
Sedimentation
Chemical Feed Systems

Raw Sewage Pumping
Sludge Pumping
Flow Measurement

B. SCOPE

This report presents estimated construction costs and operating and maintenance requirements for the previously listed process functions, as they apply to combined sewer overflow treatment and storage facilities. Construction costs are related to a single parameter, which is associated with unit size. In general, the sizes for treatment facilities correspond to design flows of from 5 mgd to 200 mgd. Storage facility sizes have been investigated for volumes of 1 million gallons to 200 million gallons.

Use of the estimating data presented in this report is dependent upon the design engineer selecting the appropriate size of unit, determining the cost of the unit process, updating the costs of the unit process, and adding other relevant plant features required for the specific project. For operation and maintenance requirements, data are presented for manpower requirements, miscellaneous supply costs, and purchased utility service and chemicals.

A format for listing and organizing the data in this report is presented. The use of this data is applicable to preliminary estimates of costs for general planning studies or for long range financial or facilities planning. Careful review of the methodology, features and components included in the cost data is encouraged if these data are used for specific project planning purposes. Comparison of alternative unit process schemes may be made; however, if costs are within 15 percent, the cost difference may not be real and more intensive costing analysis is indicated to discern real cost differences.

Another potential use of the data in this report is as a basis for project value analysis techniques. After proper usage and application of the cost data included herein for a specific project, a systematic approach of analysing function and costs may be applied. More detailed costs and material components are necessary, however, for value analysis to progress into the design phase.

During the preparation of this study, it was determined that many unit processes for combined sewer overflow treatment facilities did not exist in typical, full scale facilities, thereby requiring alternative estimating procedures. Therefore, it is prudent to review other costing information which becomes available as full scale facilities are built and placed in operation. This is particularly true of operating and maintenance costs.

A procedure for updating costs presented in this report to current costs, or to projected costs at the time of construction, is shown. The procedure is based upon the breakdown of various materials and labor costs (designated as cost components) which comprise the total construction cost of the unit process.

Component costs may be inflated using specific Bureau of Labor Statistics indices and other sources which closely parallel the cost component. Another important aspect for the user to be aware of is the difference in the design approach of facilities which exists. The basic facilities required for treatment and storage are included in these costs with no provision for subsidiary desires of the designer or user of the facility. Furthermore, the estimating data and methods presented in this report cannot in any way be used as a substitute for cost estimating based on detailed knowledge of a particular plant situation. Actual construction costs must be determined using a much more detailed knowledge of the amount of materials and labor required and a closer analysis of the availability of materials and other experience factors. The preliminary or planning estimate derived from data presented in this report or similar information must be modified to reflect the affects of the length of the project schedule, the trend of the construction economy, and local conditions which affect the costs.

C. REPORT FORMAT

The report is presented in four sections. Section II of the report discusses special considerations in the design of combined sewer overflow treatment and storage facilities and the effect these considerations may have on costs and operating requirements. Section II also presents background information on cost estimating and shows the basis of procedures used in developing costs and operation and maintenance requirements. Procedures used in evaluating inflation effects are also discussed; Section III presents the construction cost estimates for the various unit processes; Section IV presents the operation and maintenance requirements for the various unit processes; and Section V presents a format for preparing cost estimates and operating and maintenance cost estimates, based on the data presented in Sections III and IV.

SECTION II

COMBINED SEWER OVERFLOW TREATMENT AND STORAGE FACILITIES

It is presupposed that the user of this report has a knowledge of the process design, has an awareness of the need for and purpose of combined sewer overflow treatment and storage facilities and has turned to this report to obtain information for costs of unit processes. Therefore, details of design procedures and process performance are not presented except as required to explain the information contained in this report.

The application of facilities to treat or store combined sewer overflows is relatively recent and incorporates a design and operating approach significantly different from that used for conventional public waste treatment facilities. The combined sewer overflow treatment facility is to be designed for that flow, which is in excess of dry weather treatment facility capacity, and which has been determined to require treatment. The discharge may be from combined sewer overflows, or overflows from separated sanitary sewers which receive infiltration/inflow in excess of the capacity of the dry weather treatment facility; or separate stormwater runoff. The flow in each case is a periodic one and is typically large in quantity as compared to normal dry weather flows.

The treatment facilities for which research and demonstration have been concentrated are either "high rate" conventional processes or compact processes which are not typically applied in conventional systems for various reasons. The goal, of course, is to minimize the construction costs of the facility. The process selected may or may not be attractive for continuous use on dry weather flow; typically they are not.

Combined sewer overflow treatment facilities typically have a high unit cost per gallon treated because of intermittent usage and the design is likely to trade lower capital costs for higher maintenance/operating costs. On the other hand, it is important to provide automatic operation of the treatment facility via instrumentation, including automatic sampling or monitoring to assure operation upon onset of the storm and thereby relieve stationing an operator at the plant continuously prior to wet weather.

Most stormwater treatment facilities are drained and cleaned following usage. The nonoperation of the facility and the periodic testing of the facility require special consideration in design; for instance, pump bearings should be independently lubricated to permit testing in the dry. High points in pressure lines become more of a problem upon startup. Wetwells and flumes should be drainable and provisions included for removal of grit, rags, and debris. Special attention is also required for security of non-attended stations.

Sludges produced or removed in combined sewer overflow treatment facilities are many times returned to the sewer for subsequent treatment at the dry weather treatment facility. This report presumes this is the case. If it is not, special provisions should be made to store, transport, and/or condition the sludges and the cost estimate adjusted accordingly.

A. BASIS OF ESTIMATING CONSTRUCTION COSTS

Estimates are presented for construction costs and operating and maintenance requirements. Section IIIpresents the relationships of estimated construction costs to appropriate capacity parameters for each of the major facility functions. The initial investment, which includes the construction costs, as well as engineering, fiscal, administrative and land costs, may be developed on the basis of construction cost estimates.

To be generally applicable, and consistent with the earlier work(1), construction costs are presented for individual unit processes. The construction costs presented include those structural, mechanical, superstructure (if applicable), electrical and instrumentation features within the limits of the unit process. The construction cost for a unit process does not include site work such as connecting piping, roads, sidewalks, etc. To develop total construction cost estimates, it is necessary to determine the cost for each unit process in the planned project plus costs for site work. To develop total project costs, it is necessary to add appropriate amounts for engineering, land, legal, fiscal, administrative, and interest during construction.

Unit processes included in this study are applicable to combined sewer overflow treatment and storage facilities. Although certain of the unit processes are common to dry weather treatment systems, the costs are developed on the basis of the application of the unit process to combined sewer overflows.

A meager background of cost data exists which is specific to combined sewer overflow facilities. Therefore, the procedures applied to acquire cost information, by necessity, include several approaches. By far the most reliable approach to cost estimating is to make detailed quantity takeoffs from plans and specifications for the specific facility and apply appropriate unit costs. This procedure is not feasible for projects in the planning phase, because of the large amount of effort required to define facility detail.

For conventional facilities, or often used unit processes, the results of previously developed detailed cost estimates may be extrapolated to the project at hand. Extrapolation of costs requires consideration of different unit size, local variations in labor and material costs, differences in site requirements, inflation, and added or reduced ancillary systems. Although each consideration may be quantified, considerable judgement on the part of the estimator is required offering potential error in the estimate.

Alternative procedures include a thorough takeoff of a specific component and relating the cost of the facility to the component by a factor. A procedure commonly used in chemical industry is to add the costs of all major purchased equipment and multiply an appropriate experience factor times the equipment purchase cost to determine the overall facility cost; typically used factors range from 2.0 to 3.0, depending on the portion of equipment generally associated with the process. For example, experienced ratios of equipment purchase cost to total construction cost for vacuum filters range from 2.2 to 2.7 based upon detailed estimates of cost of several projects. That is, the purchase price of vacuum filter equipment represents from 1/2.7 to 1/2.2 of the total cost associated with the installed vacuum filters and associated piping, electrical, structural and other features. Again this method is subject to considerable judgement and may afford opportunity for significant error. If the process does not have a historical background of cost data, more effort and judgement are required. Such is the case with most of the unit processes associated with combined sewer overflow treatment. The most frequently used approach to estimate costs for facilities which do not have a significant historical cost background is to:

a. Define the facilities by dimension, construction material, equipment, piping and appurtenant requirements. A general plan of the facility is drawn, defining walls, overall dimensions, and structural requirements.

b. Estimate quantities of major cost components: Rules of thumb are applied to derive quantities, e.g. concrete walls - 8 inch minimum or 1 inch per foot of height; concrete footings - two thirds the quantity of wall concrete.

c. Estimate installed costs of major cost components including: concrete, equipment, piping and valves, excavation, housing.

d. Add 10 to 20 percent of sum for miscellaneous minor cost components.

e. Add 5 to 20 percent for electrical and instrumentation requirements.

The items thus determined, with an appropriate contingency factor represent the estimated construction cost of the unit process. Coupled with other unit process and plant function costs, site work and land, a total construction cost is derived.

B. INFLATING COSTS TO TIME OF CONSTRUCTION

The use of any method of cost estimating requires careful consideration of inflation. This has been especially true for the last 5 years (1970-1975) since inflation of construction costs has averaged about 9 percent per year. The rapid change in costs effects both the use of previous cost estimates to predict project costs and the planning for project cost which may be 6 months to one year away from time the planning estimate is prepared.

Many planners and engineers are accustomed to using cost indices which track costs of specific items and proportion these costs in a predetermined mixture. Unfortunately, there is all too much evidence that these time honored cost indices are not understood by the user, and/or are inadequate for many specific applications.

The basis for all cost indices used in the construction industry is to monitor the costs of specific construction material and labor cost, proportion these costs in a predetermined mixture and thereby derive an index. The most frequently used indices are probably the Engineering News Record's (ENR) Construction Cost Index and Building Cost Index.

The ENR indices were started in 1921 and were intended for general construction cost monitoring. The ENR construction cost index consists of 200 hours of common labor, 2500 pounds of structural steel shapes, 1.128 tons of Portland Cement and 1,088 board feet of 2 x 4 lumber. The ENR building cost index consists of 68.38 hours of skilled labor and the same materials as are included in the construction cost index. The large amount of labor included in the construction cost index was appropriate prior to World War II; however, on most all contemporary construction, the labor component is far in excess of actual labor used.

In fact, there should be little, if any, application of the construction cost index to water utility plant projects. This index does not include mechanical equipment, pipes and valves, which are normally associated with water utility plant construction, and the proportional mix of materials and labor are not specific to water utility construction.

To provide a more specific index, the EPA developed a sewage treatment cost index. This index was based on the cost components of a hypothetical 1 mgd trickling filter plant. The quantities of labor, materials, construction equipment and contractor's overhead and profit remain constant and the unit prices and price changes as derived from the U.S. Bureau of Labor Statistics (BLS) and ENR are applied to the constant quantities to derive the index. Because this index was specific for the process in vogue at that time and because more activated sludge plants are being constructed currently, the EPA has developed a new index based on the components of a hypothetical 5 mgd activated sludge plant and 50 mgd activated sludge plant followed by chemical clarification and filtration.

The components of cost and the proportion of cost for each index are reported to be:

Component	SCCT Index Small City Conventional Treatment (Percent)	LCAT Large City Advanced Treatment (Percent of Total)
Equipment		17.2
Civil Material and Labor	41.4	35.4
Piping Material and Labor	18.5	10.3
Electrical Material and Labor		2.7
Construction Overhead	20.7	22.5
Other	19.4	11.9

The desire for more specific indices to predict inflation or to account for price changes which have occurred previously is also reflected in other utility work. The power industry developed an index specifically for nuclear power plants which consists of weighted proportions of individual BLS indices(2). The individual BLS index proportions in the mixture were based upon experienced quantities of various components.

Obviously, the more specific an index is, the more accurately it will track cost change. The variation in inflation of various cost components cannot be monitored by a single component index. If an index is based on an improper mixture of several single component indices, it also will fail.

Therefore, to prepare construction cost estimates for stormwater facilities, this study has prepared the cost data in categories according to related cost components, to enable the costs presented to be updated and improved as more cost data are available and as inflation affects costs. Unit costs used in developing costs are presented and are applicable for June 1975. Suggested BLS indices are shown which are believed to best reflect the nature of the cost component.

Cost components presented in this report include the following:

Manufactured Equipment: This item includes estimated purchase cost of pumps, drives, process equipment and other items which are factory made and sold as equipment.

Concrete Products: This item includes the delivered cost of ready mix concrete.

Steel: This item includes reinforcing steel for concrete.

Miscellaneous Steel: This item includes steel for weirs and launders, but does not include steel pipe or structural steel for housing.

Metal Pipe and Valves: Cast iron pipe, steel pipe, valves, and fittings have been combined into a single component. This item includes the purchase price of pipes, valves, fittings, and support devices.

Concrete Pipe: The purchase price of concrete pipe is included in this item.

Housing: In lieu of segregating building costs into its several components, this component represents all material and labor costs associated with the building including heating, ventilating, air conditioning, and lighting.

Electrical and Instrumentation: The cost of electrical service and instrumentation associated with the process equipment is included in this item.

Special Construction: The provision for cost items peculiar to a specific unit process are provided in this classification.

Labor: The labor associated with installing equipment, piping and valves, constructing concrete forms and placing concrete and reinforcing steel, are included in this item.

Miscellaneous Items: Miscellaneous items provides a category for those items which have not been quantified, but with a detailed quantity takeoff would be defined. As stated, these items generally represent 10-20 percent of the total cost of the facility and include such things as handrails, access hatches, and portable and stationary miscellaneous small equipment.

Contingency: The contingency item is intended to represent costs which develop in the facility as the design requirements become better defined and also provides cushion in the event inflation exceeds the anticipated rate.

C. OPERATING AND MAINTENANCE REQUIREMENTS

The operating and maintenance requirements are fairly well established for conventional unit processes operated continuously. The operating and maintenance requirements for intermittently operated processes are not well established. Because the actual requirements cannot be assessed from field experience at this time, this report is necessarily limited to providing estimates or guidelines which may be used for a specific project. Information used in developing these guidelines was derived from the literature, from information obtained from continuously operated plants, from CWC experience of planning staff and budget requirements for specific plants, and from the meager information which is available for intermittently operated plants.

To make the information more generally usable, an attempt has been made to isolate requirements for each process function. Most utilities do not maintain records which permit distinguishing the amount of time or costs spent on each process function. In fact, this study did not uncover any information in this regard concerning intermittently operated plants.

The operating and maintenance requirements should be recognized as being based on judgement with the information available. The format presented will serve as a basis to develop data and to modify information presented herein when appropriate.

SECTION III

ESTIMATES OF CONSTRUCTION COSTS

Estimated construction costs for plant unit functions are presented in this section. Major treatment unit processes are presented first and relationships for subsystems and ancillary functions follow.

A. SWIRL COMBINED SEWER OVERFLOW REGULATOR/CONCENTRATOR

The swirl overflow regulator/concentrator is a compact unit which is used for solids removal. If site conditions and hydraulic conditions permit, no influent pumping is required and discharge from the combined sewer, through the swirl overflow regulator/concentrator to the receiving stream is by gravity. The costs presented for the swirl overflow regulator/concentrator device include only the chamber. Other plant functions which may accompany a project centered about the swirl overflow regulator/concentrator include concentrate (underflow sludge) pumping, flow measurement, disinfection, and site work. The design of the swirl overflow regulator/concentrator is based upon hydraulic principals which have been outlined (3,4). Upon selection of a design flow and efficiency, the inlet pipe diameter and swirl chamber diameter, as well as other process geometry, is defined.

Actual construction cost data and material and labor requirements for construction of a swirl overflow regulator/concentrator are not available in a form which is usable for this study. Estimated costs for the swirl overflow regulator/concentrator have been reported, however, the basis for these estimates generally reflect all project construction costs and specific site requirements. To prepare general cost information specific to the unit process, and exclusive of site improvements, interconnecting piping, and unusual soil conditions, the approach used in this report is to develop material quantities and apply current (June 1975) unit costs to a range of sizes of swirl overflow regulator/concentrators. Chamber diameters of from 12 feet to 48 feet were selected which correspond to flows of from about 5 mgd to 200 mgd. Quantities of excavation, concrete, reinforcing, steel, labor and piping were determined for the estimated facility requirements. Unit costs were applied to the determined quantities to derive an estimated cost of construction. Unit prices have been selected from Richardson's Engineering Services, Inc.(5), Means Building Construction Cost Data 1975 (6), and the 1975 Dodge Guide(7), and are considered typical for mid 1975 (June). Unit prices for materials and labor which have been used in this study are summarized in Appendix B.

A typical layout plan for a swirl overflow regulator/concentrator is shown on Figure 1. Estimated construction costs for the swirl overflow regulator/concentrator are shown by cost component on Table 1 and are shown graphically on Figure 2. Costs are presented as a function of the chamber surface area.

TABLE 1

ESTIMATED CONSTRUCTION COSTS

SWIRL OVERFLOW REGULATOR/CONCENTRATOR

Cost Component	Surface Area (Square Feet)						
	113	254	452	707	1018	1385	1810
Manufactured Equipment	10,500	16,500	22,500	28,500	34,500	40,500	48,000
Concrete	600	1,340	2,220	3,500	5,120	8,470	12,970
Steel	2,480	4,885	8,305	13,250	20,580	30,425	42,530
Labor	4,075	9,765	17,770	29,650	45,355	68,560	95,100
Metal Pipe and Valves	-	-	-	-	-	-	-
Concrete Pipe	-	-	-	-	-	-	-
Housing	-	-	-	-	-	-	-
Electrical and Instrumentation	3,000	3,200	3,400	3,600	3,800	4,000	4,200
Miscellaneous Items	3,100	5,350	8,130	11,780	16,400	22,790	30,420
Contingency	3,560	6,160	9,350	13,540	18,860	26,210	34,980
TOTAL ESTIMATED COST	27,315	47,200	71,675	103,820	144,615	200,955	268,200

The cost of the swirl overflow regulator/concentrator includes the basic chamber, which does not include roof, pumping stations, flow measurement or basin dewatering facilities. These items, if applicable, must be added to derive a total estimated project cost. The chamber dewatering facility is normally incorporated in the sludge (or concentrate) pumping station or concentrate discharge facilities. Costs for raw wastewater pumping stations, sludge (or concentrate) pumping stations, and flow measurement facilities are presented later in this section.

The previously reported estimates for swirl overflow regulator/concentrators, although not presented in a format directly related to the approach used in this study, may be used with other data to reflect on the comparability of these estimates. Three sources of data are available:

Location	Swirl Chamber Size Diameter (ft)	 Area (SqFt)	Cost Basis	Reference
1. Syracuse, New York	12	113	Construction Bids	(4)
2. Lancaster, Pennsylvania	22	380	Engineer's Est.	(8)
	32.5	830	Engineer's Est.	(8)
3. -	22.5	400	General Est.	(9)
	29.5	680	General Est.	(9)
	36.0	1020	General Est.	(9)

The Syracuse, New York unit reports the following construction costs:

	Reported Costs	Current Equivalent Cost*	Portion Attributable To Swirl Unit
Site Work	$18,700	$20,570	-
Piping	19,700	21,670	-
Swirl Chamber	19,700	21,670	21,670
Electrical	4,100	4,510	4,510
Miscellaneous	3,500	3,850	1,925
	$65,700	$72,270	$28,105

* (1974 to 1975 inflation = 1.10)

The estimate presented in this report does not include site work which represents a large portion of the costs of the above installation. The swirl chamber, electrical cost, and a portion of the miscellaneous cost will be attributable to the swirl overflow regulator/concentrator as a unit process, and the other items are attributable to site work. This report estimates the cost of a similar size unit as $27,300. Assuming 1/2 of the miscellaneous costs, all electrical and swirl chamber costs are attributable to the swirl overflow regulator/concentrator, the Syracuse project results in $28,105.

The Lancaster, Pennsylvania engineering estimates for two swirl overflow regulator/concentrators are as follows:

Diameter of Chamber (ft)	22	32.5
Surface Area of Chamber (SqFt)	380	830
Concrete	$ 55,000	$127,000
Excavation	11,000	16,000
Miscellaneous Metal	22,000	32,000
Roof	4,000	7,000
Valves and Gates	6,000	10,000
Paint	3,000	6,000
Ventilation	2,000	4,000
Total Estimated Cost	$103,000	$202,000
Estimated Cost This Study	70,000	150,000

Without detailed knowledge of each of these projects, it is not possible to make a comparison of costs with estimates presented herein; for instance, the 22 foot diameter chamber has an estimated amount of concrete equaling 60 yards. The Lancaster project estimated cost for concrete being 55,000 dollars for the 22 feet diameter chamber indicates a quantity of concrete equalling 220 cubic yards (assuming $250/yard). Similar inconsistencies may be shown for other item estimated costs indicating the above projects include significant features other than the swirl chamber.

The estimates presented for the swirl overflow regulator/concentrator in the EPA report(9) on the Helical bend overflow regulator are shown below:

	Estimate	Attributable To Swirl	Estimate	Attributable To Swirl	Estimate	Attributable To Swirl
Chamber Diameter	22.5		29.5		36	
Item						
Sheet Pile	17,200	-	24,940	-	32,250	
Excavation	7,360	7,360	14,400	14,400	21,760	21,760
Reinf. Conc.	31,948	31,948	50,856	50,856	70,416	70,416
Superstructure	3,789	-	3,789	-	3,789	-
Outlet Pipes	1,300	1,300	3,000	3,000	4,000	4,000
Downshaft Plate	2,000	2,000	3,000	3,000	5,000	5,000
Miscellaneous Cost*	9,540	9,540	15,000	15,000	20,580	20,580
Contingency*	10,970	10,970	17,250	17,250	23,670	23,670
Bypass Sewer	10,000	-	19,500	-	28,000	-
TOTAL	94,107	63,118	151,735	103,506	209,465	145,426
Estimated Cost This Study	-	72,000	-	105,000	-	145,000

* Revised percentages to conform to those used in this study

The estimates presented in this study are supported by previous costs and estimates. The exercise developed above does emphasize the significance of unusual site conditions and site work costs.

B. SCREENING

There are three types of screening devices for which cost data have been prepared. The generic designations for the devices used in this presentation are as follows:

Stationary Screen - A wedgewire screen where waste is discharged across a sloping screen section causing solids to be removed and discharged by gravity while the screened wastewater discharges through the screen to a collector flume below.

Horizontal Shaft Rotary Screen - This screen is often referred to as a microscreen or microstrainer. The wastewater enters the interior of a slowly rotating drum and discharges through the screen into a collection chamber.

Vertical Shaft Rotary Screen - Wastewater enters the interior chamber of a high speed rotary screen and passes through the rotating screen to discharge while the screened solids are washed out as a concentrated underflow. Sweco is the predominate manufacturer of this screen.

1. Stationary Screen - The stationary screen is designed on the basis of experienced data; flow rates and performance have been previously reported (10,11). The screen assembly and configuration requires about 7 to 8 feet of hydraulic head loss; however, recent lower head models are available which require 3 to 4 feet of hydraulic head loss. Contacts were made with manufacturers of the equipment, and although equipment cost was made available, total project cost data were inadequate for the purposes of this study. Therefore, several plant layouts were made and quantities estimated for the necessary facilities. A typical section of the facilities included in the costs are shown on Figure 3.

The manufacturers rate various size screens for specific peak flows. For example, the 72 inch wide screen, having one screen face, is rated at 2 million gallons per day (mgd) peak flow and the 72 inch wide screen having two screen faces is rated at 4 mgd. For the purposes of this study, the facilities were based on three screens, each rated at 4 mgd, 12 mgd total, to 48 screens rated at 192 mgd total. Costs are related to hydraulic capacity.

Collection flumes for sludge and screened effluent are provided. The sludge is of sufficient concentration that it will not flow and it is presumed to be sluiced to return to the sewer by adding water (or unscreened wastewater) as a conveying medium. Equal hydraulic distribution to several units is problematical, especially, when up to 48 units are required. To provide for the capability of flow splitting, oversized open channels are included as influent headers and metal weirs are included at each screen unit; this would permit equal head at each unit influent weir and essentially equal flow to each screen unit.

Housing is included in the cost of the facility. The cost components for stationary screens are shown in Table 2 and estimated construction costs are shown graphically on Figure 4.

Additional functional units which may be required for a complete project include a raw wastewater pumping station, flow measurement, disinfection, and site work for which costs are presented later in this report.

2. Horizontal Shaft Rotary Screen - The application of horizontal shaft rotary screens are varied. Different aperture fabrics provide for removal of large solids to small solids. This permits use of the screen for purposes ranging from pretreatment to final treatment. Design and performance information have been presented previously(12,13,14,15).

Horizontal screens are designed on the basis of experience. The basic design parameter is gallons per minute per square foot based on surface area exposed to the wastewater. Screen submergence typically varies from 74 percent to 83 percent.

TABLE 2

ESTIMATED CONSTRUCTION COSTS

STATIONARY SCREEN

Cost Component	Capacity - (mgd)				
	12	32	64	128	256
Manufactured Equipment	39,600	105,600	211,200	422,400	844,800
Concrete	1,800	2,800	5,600	11,200	22,400
Steel	250	700	1,360	2,720	5,440
Labor	23,100	62,900	125,800	251,600	503,200
Metal Pipe and Valves	7,200	20,800	43,340	86,680	173,360
Concrete Pipe	-	-	-	-	-
Housing	30,600	57,120	114,240	228,480	456,960
Electrical and Instrumentation	5,130	12,500	25,080	50,150	100,310
Miscellaneous Items	16,150	39,360	78,990	157,980	300,920
Contingency	18,570	45,270	90,840	181,680	346,060
TOTAL ESTIMATED COST	142,400	347,050	696,450	1,392,890	2,653,140

The screen is installed in a chamber designed to permit entry of the wastewater to the interior of the drum and collection of filtered (or screened) wastewater from the exterior side of the drum. Inlet and outlet piping is typically arranged in a fashion similar to granular media filters. A general layout of an installation and piping for horizontal shaft rotary screens is shown on Figure 5. A limited amount of data was made available from screen installations, however the data format and the lack of material quantity information prevents the use of the data. To obtain costs for various capacity and sizes of installations, representative layouts were made and major material and equipment items quantified. Concrete construction was used as a basis, with a center pipe gallery. Housing for the gallery and screen chambers are included. Distribution to each filter unit is based on influent rate control linkage between an insert differential flow measurement device and throttling valve. Appurtenances include ultraviolet light slime growth control, backwash sprays, and backwash storage and pumping facilities.

A summary of the cost components used in this study are shown on Table 3. For the current cost relationship to screen area, the data are presented graphically on Figure 6.

Associated costs which may be applicable to projects which utilize drum type screens include raw wastewater pumping and chlorination which are present later in this report.

TABLE 3

ESTIMATED CONSTRUCTION COSTS

HORIZONTAL SHAFT ROTARY SCREEN

Cost Component	Screen Area - (Square Feet)				
	315	630	1260	2520	5040
Manufactured Equipment	66,850	133,690	248,110	496,220	992,440
Concrete	2,200	4,300	6,200	12,400	24,800
Steel	5,920	11,300	14,460	28,920	57,840
Labor	42,000	84,700	142,160	284,320	568,640
Metal Pipe and Valves	20,110	44,380	85,890	171,780	343,560
Concrete Pipe	-	-	-	-	-
Housing	21,000	42,000	58,800	117,600	235,200
Electrical and Instrumentation	31,620	64,080	111,120	222,240	444,480
Miscellaneous Items	28,460	57,670	100,010	200,020	400,040
Contingency	32,720	66,320	115,010	230,010	460,020
TOTAL ESTIMATED COST	250,880	508,440	881,760	1,763,510	3,527,020

Syracuse, New York has experienced cost data for screen installations. The project at Syracuse, New York consisted of a raw wastewater pumping station, a vertical shaft rotary screen (rated at 5 mgd), two horizontal shaft rotary screens (each rated at 5 mgd), and chlorination facilities. The cost breakdown for this project is as follows:

Item	Cost	Inflated Cost*
Pumping Stations	120,700	132,770
Screen Housing	96,100	105,710
Vertical Shaft Screen	37,500	41,250
Horizontal Shaft Screens(2)	73,000	80,300
Valves and Piping	23,600	25,960
Chlorination Equipment	14,500	15,950
Electrical/Instrumentation	25,800	28,380
Miscellaneous Items	10,700	11,770
Site Work	40,200	44,220
TOTAL	442,100	486,310

*From 1974 to mid 1975, factor = 1.10

Separating costs of the screening function from these costs is not precise, however, a relative value may be derived. Excluding site work, chlorination and the raw wastewater pumping station, and a proportional amount of valves, piping, electrical work and miscellaneous items, the screening (all) facilities represent about 263,000 dollars. The three screening units may be considered to represent 300 square feet of screening area ignoring the inconsistency that one screen is a vertical shaft unit. Figure 6 of this report estimates this area of screen to cost 250,000 dollars. This analysis, by necessity cursory, but tends to support the lower range of cost estimates presented herein.

3. Vertical Shaft Rotary Screen - There is no ready dimensional parameter to relate costs of vertical shaft rotary screens. The various size units which are available are rated for specific capacities; therefore, the cost data have been developed on a flow relationship basis. Design and performance data have been presented for a pilot plant in Portland, Oregon(16,17). Because of the relatively low capacity of the individual units, as compared to the large volume to be treated, the cost data have been developed on the basis of multiples of the largest unit available, (60 inch screen by Sweco, Inc.) which is rated at 3 mgd.

A typical cross section of a unit with feeder piping is shown on Figure 7. Auxilaries to the unit include hot and cold water sprays and detergent cleaners. The operation of a multiple screen installation has been based on activating only those numbers of units required for the flow received. A flow meter with multiple set contacts to operate individual screen units is presumed. An example of a layout for multiple screen installation used for the basis of the cost data in this study is shown on Figure 7. The cost components which compose various capacity screen installations are shown on Table 4, and current cost estimates are shown on Figure 8.

As with the horizontal shaft rotary screen, no isolated costs, strictly attributable to the vertical shaft rotary screen are available. The Syracuse project included one unit which was bid at $41,250 (current dollars) and would represent an installed cost including housing, and associated appurtenances of about $88,000. The single screen unit would correspond to a 3 mgd flow basis. This roughly corresponds to one quarter of the 12 mgd data point on Figure 9.

C. AIR FLOTATION

Air flotation is a unit process designed primarily on the basis of surface area, much like sedimentation. Air flotation performance and design information has been presented previously(18). Air flotation equipment is furnished in package units which include the basins, or equipment for custom built basins. The largest practical size individual unit is about 20 feet wide and 100 feet long. Unlike many of the previously presented unit processes, capital cost data with detailed quantity takeoffs were obtainable and used to assist in verification of synthesized cost data; however, for the most part, the data were developed on the basis of sizing, providing preliminary structural design, and quantifying major cost components.

TABLE 4

ESTIMATED CONSTRUCTION COSTS

VERTICAL SHAFT ROTARY SCREENS

Cost Component	Capacity (mgd)				
	12	36	72	144	216
Manufactured Equipment	85,600	256,510	504,000	1,008,000	1,512,000
Concrete	5,160	14,850	36,400	74,950	109,200
Steel	3,760	9,930	19,850	39,700	59,550
Labor	51,000	155,800	315,600	633,700	950,550
Metal Pipe and Valves	19,800	59,400	116,800	237,600	350,400
Concrete Pipe	4,000	23,300	49,000	103,900	155,800
Housing	52,800	134,400	268,800	537,600	806,400
Electrical and Instrumentation	44,420	130,840	262,090	527,090	788,800
Miscellaneous Items	39,980	117,750	235,880	474,380	709,900
Contingency	45,980	135,420	271,260	545,540	816,390
TOTAL ESTIMATED COST	352,500	1,038,200	2,079,680	4,182,460	6,258,990

A typical plan of an installation is shown on Figure 9. Flow splitting is provided by splitter boxes consisting of an influent riser well and equal length weirs for individual units. An enclosed piping and equipment gallery is provided between units for collector drive equipment, recirculation pumps, air dissolving tanks and other miscellaneous equipment.

A summary of the estimated cost components are shown on Table 5, and the current estimated costs for air flotation are shown on Figure 10. Other unit processes which are typically associated with air flotation in combined sewer overflow treatment include rapid mix, flocculation, prescreening with 50 mesh drum screens, chlorination, and raw wastewater pumping. Costs for these processes unit functions are presented later in this report.

TABLE 5

ESTIMATED CONSTRUCTION COSTS

AIR FLOTATION

Cost Component	Surface Area - (Square Feet)							
	400	800	1,600	3,200	6,400	12,800	25,600	51,200
Manufactured Equipment	58,880	86,940	110,740	200,100	303,000	486,000	820,000	1,400,000
Concrete	5,780	7,780	11,850	20,010	31,630	51,560	66,330	120,000
Steel	16,150	23,660	33,670	53,690	84,860	138,350	235,070	400,000
Labor	39,450	51,480	71,170	123,280	194,850	317,680	539,770	920,000
Metal Pipe and Valves	2,000	4,000	5,400	6,200	9,800	15,980	27,150	45,000
Concrete Pipe	-	-	-	-	-	-	-	-
Housing	-	-	-	-	-	-	-	-
Electrical and Instrumentation	24,450	34,770	46,570	80,660	124,830	201,910	337,660	577,000
Miscellaneous Items	22,010	31,290	41,910	72,590	112,350	181,720	303,900	520,000
Contingency	25,310	35,990	48,200	83,480	129,200	208,980	349,480	600,000
TOTAL ESTIMATED COST	194,030	275,910	369,510	640,010	990,520	1,602,180	2,679,360	4,582,000

The significant combined sewer overflow project using air flotation is the Racine, Wisconsin project. This project consists of three sites of which two included air flotation units. The two project sites involving air flotation each consisted of bar screens, raw wastewater pumping station, parshall flume, flow measurement, drum screens, air flotation, coagulant chemical feed system and chlorination. Site I included 3 - air flotation units having a total surface area of 3,000 square feet. Site II included 8 air flotation units having a total surface area of 8,000 square feet. The purchase cost of the air flotation equipment was 43,000 dollars and 117,000 dollars for the two sites,respectively. Updating these costs from 1971 (factor = 1.70) to present,and adding installation costs, a current installed cost would be 90,000 and 240,000 dollars respectively. A total cost including associated structure,piping,valves, electrical,and instrumentation would be 300,000 and 800,000 dollars. This data contradicts experienced data for air flotation units installed as solids concentration devices in other facilities.

The EPA report(19) on suspended solids removal presents data which indicate the capital cost would be 550,000 and 1,260,000 dollars for these basins based on an EPA index of 235. These cost estimates support those presented in this study. The Racine project costs appear to be low. The data presented in this report may reflect higher costs than will be experienced, however, for planning purposes general cost data should not reflect the lowest cost data found.

D. CHLORINATION

Because of the characteristic intermittent operation associated with treatment of combined sewer overflows, reduction of construction cost with a potential increase in operating costs often results in overall minimum costs. In the case of chlorination facilities as applied to treatment of combined sewer overflows, the construction costs associated with contact basins having conventional detention time of from 15 to 30 minutes is high and difficult to justify. Therefore, consideration of higher mixing intensities to make better usage of the chlorine and/or higher chlorine dosages and shorter detention time contact basins to effect the same end results should be given.

The form of chlorine used at a facility for treatment of combined sewer overflows should be adaptable to intermittent use. Other considerations include the disinfection effectiveness of the chlorine form, and the safety and ease of feeding. Because application conditions vary and because local conditions vary, the options of the form of chlorine to be fed are many. The scope of this study is limited to chlorine forms.

Chlorine is normally fed as a gas, or liquid solution. The safety, methods of feeding, storage provisions, disadvantages, and advantages of each are well documented(20). The forms most often considered for use in treatment of combined sewer overflows and the primary justification given for that selection are as follows:

Chlorine Form	Feeder	Reason For Use
Chlorine Gas	Gas Feeder	Ease of feeding; minimum storage
Hypochlorite	Solution	Safety
Chlorine Dioxide	Solution	Does not combine with ammonia; disinfection capability is excellent

The feeder, storage, and housing facilities for each form are presented in the following pages.

1. Chlorine Gas - The most prevalent form of chlorine fed in the water utility industry today is chlorine gas. The equipment and storage facilities requirements are well known and commercial equipment is readily available. Construction costs for chlorine feed equipment have been presented previously(1); however, these costs were based upon continuous-use facilities with long term storage housing requirements. For the purposes of treatment of combined sewer overflow, the previous costing information has been reviewed in light of current costs and reduced storage area requirements.

The previous work(1) cites the difficulty in isolating costs for the chlorine feed and storage facilities. Most often, the chlorine feed and storage facilities are combined with other structures, making analysis difficult. A typical chlorine feed and storage facility, for which the capital costs presented herein represent, is shown on Figure 11. Ton cylinders are shown; however, for less than 1,000 pounds per day feed rate, 150 pound cylinders were used as a basis of storage requirements.

Several quantity take-offs of similar chlorine feed and storage facilities were reviewed. Of seven installations, the installed chlorination system facility was estimated to cost from 2.5 to 3.5 times the purchase price of the chlorinators. The average estimated installed cost of the seven installations was 3.0 times the quoted purchase price of the chlorinators above.

The total installed cost includes distribution panels, cylinder chocks, installation, manufacturer's preparation of shop drawings, installation check and startup, and contractor's overhead and profit. Chlorinator costs include one standby chlorinator. Evaporators are included on systems having a capacity greater than 4,000 pounds per day.

Miscellaneous piping varies significantly depending on the layout. For the layout shown on Figure 11, piping costs will vary from 5 to 10 percent of the installed chlorination equipment cost.

Hoist equipment will be essentially constant for electrically operated, monorail trolley hoists. For large storage areas having long rails and extensive duct-o-bar electrical systems, the costs will approach 30,000 dollars for a 30 cylinder storage system or 1,000 dollars per cylinder. Manually operated hoists systems are less expensive (about half) but require more labor for loading and unloading. For the purposes of this analysis, hoisting equipment is estimated at 0.50 dollars per pound of cylinder storage capacity.

A summary of the cost components and current estimating cost curve is shown on Table 6 and Figure 12 respectively.

TABLE 6

ESTIMATED CONSTRUCTION COSTS

GASEOUS CHLORINE FEED FACILITIES

Cost Component	Chlorine Feed Capacity (pounds per day)				
	100	1,000	4,000	8,000	12,000
Manufactured Equipment	2,760	15,100	38,300	78,000	87,000
Concrete	-	-	-	-	-
Steel	-	-	-	-	-
Labor	960	5,250	13,400	27,400	30,600
Pipe and Valves	330	1,650	3,630	7,490	8,510
Concrete Pipe	-	-	-	-	-
Housing	3,300	11,880	15,840	32,100	37,900
Electrical and Instrumentation	1,100	5,100	10,700	21,800	24,700
Miscellaneous Items	1,270	5,850	12,280	25,060	28,380
Contingency	1,460	6,720	14,120	28,820	32,640
TOTAL ESTIMATED COST	11,180	51,550	108,270	220,970	250,230

2. Chlorine Dioxide - The feeding and storage facilities for chlorine dioxide essentially include additional requirements to that described for chlorine gas. The most common method of generating chlorine dioxide in the water utility industry is reacting chlorine solution with sodium chlorite solution. Chlorine dioxide may also be formed using sodium chlorate, sulfuric acid, and sodium chloride; however, this method will not be presented in this cost analysis.

In practice, one pound of chlorine dioxide is formed by mixing 1.68 pounds of chlorine with 1.68 pounds of sodium chlorite in a reaction tower for approximately one minute. A schematic of the facility requirements is shown on Figure 13.

Chlorine dioxide facilities are not common in the water utility industry; and therefore, established cost information is minimal. The costs presented are based on those costs for gas chlorination systems plus estimated requirements and costs for the added facilities for chlorine dioxide. Chlorine dioxide does not combine with ammonia, and the disinfection capability is greater than chlorine for combined sewer overflows. As a result, lower doses of chlorine dioxide, as compared to chlorine, may be feasible; however, the reported costs presented herein are for a similar range to that presented for chlorine.

The facilities required for chlorine dioxide feeding are summarized in Table 7 and the estimating costs for the facilities are shown in Table 8 and on Figure 14. For feed rates of 2,400 pounds per day and more, a hand truck with barrel grabs has been included to handle and empty sodium chlorite containers.

TABLE 7

FACILITY REQUIREMENTS FOR CHLORINE DIOXIDE FEED

Feed Rate (Pounds Per Day)	Chlorine Feeder (Pounds Per Day)	Proportioning Pump Capacity (Gallons/Hour)	Sodium Chlorite Solution Tank (Gallons)	Sodium Chlorite Storage Area (Square Feet)
60	100	1.5	36 (55 gal.drum)	0
600	1,000	15	360 (4.5 ft.diam.)	100
2,400	4,000	60	1,440 (9 ft.diam.)	264
4,800	8,000	120	2,880 (2.75 ft.diam.)	528
7,200	12,000	180	8,320 (3.75 ft.diam.)	792

TABLE 8

ESTIMATED CONSTRUCTION COSTS

CHLORINE DIOXIDE FEED FACILITIES

Cost Component	Design Feed Rate (pounds per day)				
	60	600	2,400	4,800	7,200
Manufactured Equipment	4,760	20,300	58,400	114,100	138,900
Concrete	-	-	-	-	-
Steel	-	-	-	-	-
Labor	1,660	7,100	20,450	39,900	48,600
Metal Pipe and Valves	660	3,300	7,260	14,980	17,000
Concrete Pipe	-	-	-	-	-
Housing	5,280	17,820	26,730	51,700	66,100
Electrical and Instrumentation	1,850	7,280	16,900	33,100	40,600
Miscellaneous Items	2,130	8,370	19,460	38,070	46,680
Contingency	2,450	9,630	22,380	43,780	53,680
TOTAL ESTIMATED COST	18,790	73,800	171,580	335,630	411,560

3. Hypochlorite - The recent escalation of chlorine prices and the safety advantages of hypochlorite versus chlorine gas have stimulated interest in hypochlorite disinfection facilities. The on-site storage of hypochlorite and the limited shelf life of hypochlorite has directed this interest toward on-site generation. Facility requirements for hypochlorite require electrolytic cells, brine (sodium chloride) feed, and storage and hypochlorite feed and storage. A typical facility is schematically shown on Figure 15.

There are several commercially available package hypochlorite generation systems including:

Diamond Shamrock "Sanilec"
Englehard "Chloropac"
Ionics "Cloropat"
Pepcon "Pep-Chor"

Several small installations of on-site hypochlorite processes are on-line; however, cost information in the water utility industry is generally lacking. Prices from manufacturers have been obtained, and general installation cost estimating procedures have been used. Housing is included for transfer pumps, electrodes, and rectifier, as well as auxiliaries. Hypochlorite and salt-storage is included in the estimated construction costs presented and are assumed to be in outdoor tanks.

The components used in estimating costs are shown on Table 9 and the current estimated costs for hypochlorite feed are shown on Figure 16.

TABLE 9

ESTIMATED CONSTRUCTION COSTS

HYPOCHLORITE GENERATION FACILITIES

Cost Component	Design Feed Rate (pounds per day)						
	250	500	1,000	2,000	4,000	8,000	12,000
Manufactured Equipment	84,000	114,000	195,000	310,000	620,000	1,240,000	1,860,000
Concrete	-	-	-	-	-	-	-
Steel	-	-	-	-	-	-	-
Labor	29,000	39,000	65,000	100,000	186,000	372,000	558,000
Pipe and Valves	940	1,240	1,650	2,500	3,630	7,490	8,510
Concrete Pipe	-	-	-	-	-	-	-
Housing	10,800	15,000	20,000	29,000	58,000	116,000	174,000
Electrical and Instrumentation	18,700	25,390	42,250	66,230	130,150	260,300	390,100
Miscellaneous Items	21,520	29,190	48,590	76,160	149,670	299,370	448,590
Contingency	24,740	33,570	55,870	87,580	172,120	344,280	515,880
TOTAL ESTIMATED COST	189,700	257,390	428,360	671,470	1,319,570	2,639,440	3,955,080

E. HIGH INTENSITY MIXING/CHLORINE CONTACT BASIN (RAPID MIX)

As noted in the discussion under chlorination of combined sewer overflows, conventionally long contact times may not be economically justifiable. Short term contact times with more intense mixing have been studied to effect the same disinfection results. As one means of providing facilities for short term contact, a basin and (13.15) mixer, not unlike a rapid mix chamber used in coagulant mixing are included in this presentation. Cost data presented for this function may also be used for estimating rapid mix basin costs.

The costs of the facility are based on reinforced concrete construction and stainless steel mixers. The mixing intensity, or mixer horsepower per unit volume, significantly influences the cost of the mixing basin. Costs for two levels of mixing intensity are provided in the cost data, corresponding to a velocity gradient, G, of 100 hr^{-1} and 300 hr^{-1}. A summary of the component breakdown of costs is shown on Table 10 and is shown graphically on Figure 17.

TABLE 10

ESTIMATED CONSTRUCTION COSTS

HIGH INTENSITY MIXING/CHLORINE CONTACT BASIN (RAPID MIX)

$G = 100\ hr^{-1}$

Cost Component	Volume (Cubic Feet)					
	1,400	2,800	5,000	10,000	18,500	37,000
Manufactured Equipment	2,000	2,500	3,000	4,000	6,000	12,000
Concrete	1,120	1,800	2,360	3,800	6,000	10,800
Steel	2,280	3,590	4,620	7,400	11,510	20,720
Labor	3,780	5,820	7,350	13,620	19,400	34,920
Electrical	1,840	2,740	3,470	5,760	8,580	15,690
Miscellaneous Items	1,650	2,470	3,120	5,190	7,720	14,120
Contingency	1,900	2,840	3,590	5,960	8,880	16,240
TOTAL ESTIMATED COST	14,570	21,760	27,510	45,730	68,090	124,490

$G = 300\ hr^{-1}$

Cost Component	Volume (Cubic Feet)					
	1,400	2,800	5,000	10,000	18,500	37,000
Manufactured Equipment	6,000	12,000	20,000	24,000	34,000	100,000
Concrete	1,120	1,800	2,360	3,800	6,000	10,800
Steel	2,280	3,590	4,670	7,400	11,510	20,720
Labor	5,180	9,150	13,300	20,620	29,200	65,720
Electrical	2,520	3,980	6,050	8,370	12,110	29,590
Miscellaneous Items	2,890	4,580	6,960	9,630	13,920	34,020
Contingency	3,330	5,270	8,000	11,070	16,010	39,130
TOTAL ESTIMATED COST	23,320	40,370	61,340	84,890	122,750	299,980

F. FILTRATION

High rate filters have been applied to combined sewer overflows in conjunction with other unit processes, such as chemical coagulation, drum screens and chlorination. High rates (16-24 gallons per minute per square foot) can be considered when applying stormwater(21,22). Unlike other unit processes discussed, there is a large backlog of costing data on filtration, primarily developed from water treatment plant experience.

The information presented herein is based on concrete gravity filters, exclusive of chemical treatment features and other unit processes. Costs are included for backwash and surface wash of filters. Although head losses of up to 30 feet have been reported in small bench scale filter units, the practicability of providing freeboard to this headloss capability is questionable. Consideration of pressure filters for operations of in excess of 12 to 15 feet of headloss should be given.

Media costs are based on dual, nonproprietary media. In general, media depths are two to three times greater than for conventionally designed filters, and the media is generally coarser.

Other design considerations should include prescreening drum filters, backwash supply storage, and influent flow equalization. This may be incorporated into basins preceding the filters which afford sufficient volume to avoid rate increases when a filter is removed from service for backwashing and also provide sufficient volume for backwash.

The general considerations of any combined sewer overflow treatment plant include automatic operation. Instrumentation for automatic filter backwash is included.

A general physical layout of the filters is shown on Figure 18. Housing of the filters and filter galleries is included, but may not be applicable in warmer climates. Cost components are shown in Table 11 and current cost estimates are shown on Figure 19.

TABLE 11

ESTIMATED CONSTRUCTION COSTS

FILTRATION

Cost Component	Surface Area (Square Feet)			
	2,740	4,320	9,400	15,540
Manufactured Equipment	193,800	221,800	315,000	416,600
Concrete	60,300	87,950	117,600	264,700
Steel	101,470	150,080	252,870	327,340
Labor	361,100	411,100	934,000	1,341,250
Metal Pipe and Valves	170,200	180,560	202,000	380,200
Media, Underdrains, Troughs	94,600	140,000	307,500	508,000
Housing	106,110	165,600	350,000	596,400
Electrical and Instrumentation	163,140	203,560	371,850	575,170
Miscellaneous Items	187,610	234,110	427,620	661,470
Contingency	215,750	269,210	491,760	760,660
TOTAL ESTIMATED COST	1,654,080	2,063,970	3,770,200	5,831,790

G. STORAGE

The typical storm hydrograph is characterized by having a high instantaneous peak flow which is extreme in comparison to the average volume of the wastewater during the storm. The concept of providing storage to either reduce the capacity of combined sewer overflow treatment facilities, or to eliminate stormwater treatment facilities is popular. Several innovative storage concepts have been proposed such as collapsible underwater bladders, deep underground reservoirs, and short term flooding of open spaces.

These concepts require detailed analysis in light of the specific project. For the purposes of this preparation, storage of combined sewer overflows is restricted to concrete basins and lined earthen reservoirs.

The application of storage to combined sewer overflows may also include provisions for mechanical sludge collection; however, for strictly storage purposes, the economics of providing mechanical sludge collection is questionable. The costs for earthen reservoirs is primarily associated with the moving and compacting of soil and the cost of the paving or liner, if used. The earthmoving costs are highly dependent on the shape of the basin, borrow requirements, soil type, and ground water problems. The costs presented for earthen reservoirs presume embankment soil is obtained on-site, no rock excavation and minimal ground water problems. In urban areas, the likelihood of avoiding these complications is rare and exceptional contingencies should be provided for in any general planning study or unexplored site. The basis of estimating costs for earthen reservoirs are a 2.5 to 1 interior slope, a 3:1 exterior slope, 20 percent compaction loss and a 16 foot top width of levee. The reservoir is presumed to be 18 feet deep and 2 times as long as it is wide. The reservoir bottom is sloped at 2 percent to facilitate cleaning after each storm. Costs for concrete slope paving or synthetic material liners are included. No cover is included. The cost components of earthen reservoirs are presented in Table 12 and current costs are shown on Figure 20.

TABLE 12

ESTIMATED CONSTRUCTION COSTS

EARTHEN STORAGE RESERVOIRS

Cost Component	Volume (million gallons)							
	0.57	1.95	4.90	9.20	14.80	50.85	108.50	187.80
Earthwork	2,540	6,670	14,900	24,700	36,940	93,330	156,320	229,530
Liner	7,730	14,350	32,780	53,720	79,650	233,400	467,150	780,900
Paving	2,180	3,140	4,340	5,540	6,740	11,540	16,340	21,140
Seeding	870	1,750	3,150	4,960	6,540	13,800	20,600	28,000
Fencing	5,650	7,940	10,720	13,500	16,100	26,300	26,300	45,900
Miscellaneous Items	2,850	5,100	9,900	15,360	21,900	56,700	103,000	165,820
Contingency	3,270	5,790	11,350	17,650	25,210	65,150	118,290	190,430
TOTAL ESTIMATED COST	25,090	44,740	87,140	135,430	193,080	500,220	908,000	1,461,720

Costs for concrete reservoirs have been prepared for covered basins as well as uncovered basins. Covered basins may be applicable in parks or congested areas where the surface of the reservoir may serve for recreational purposes. Uncovered basins are applicable in industrial districts or in undeveloped areas. The cost of covers are based on precast concrete members with no provision for special toppings or earth cover. Accessways for personnel are provided in the costs.

The costs for the reservoir are shown by cost component on Table 13. Current estimated costs are presented in Figure 20.

TABLE 13

ESTIMATED CONSTRUCTION COSTS - CONCRETE STORAGE RESERVOIRS

CONCRETE RESERVOIRS WITHOUT COVERS

Cost Component	Volume (million gallons)								
	1.0	2.0	4.0	7.5	15.0	30.0	60.0	120.0	240.0
Concrete and Forms	80,370	109,030	166,360	230,390	358,450	513,270	822,940	1,239,770	2,073,370
Steel	110,400	149,600	277,200	313,600	486,400	692,000	1,104,000	1,648,800	2,739,200
Labor	99,140	135,850	208,610	294,060	465,840	686,800	1,129,260	1,771,140	3,055,330
Miscellaneous Items	43,490	59,170	97,830	125,710	196,600	283,810	458,430	698,960	1,180,190
Contingency	50,010	68,050	112,500	144,560	226,090	326,380	527,190	803,800	1,357,210
TOTAL ESTIMATED COST	383,410	521,700	862,500	1,108,320	1,733,380	2,502,260	4,041,820	6,162,470	10,405,300

ADDITIONAL COSTS FOR CONCRETE RESERVOIRS WITH COVERS

Cost Component	Volume (million gallons)								
	1.0	2.0	4.0	7.5	15.0	30.0	60.0	120.0	240.0
Concrete and Forms	5,150	15,450	30,900	72,100	144,200	309,000	618,000	1,277,200	2,544,400
Steel	2,650	7,950	15,900	37,100	74,200	159,000	318,000	657,200	1,314,000
Labor	10,150	23,450	46,900	100,100	200,200	413,000	826,000	1,677,200	3,354,400
Precast Concrete	20,000	40,000	160,000	320,000	640,000	1,280,000	2,560,000	5,120,000	10,240,000
Roofing Material	2,000	4,000	16,000	32,000	64,000	128,000	256,000	512,000	1,024,000
Miscellaneous Items	6,000	13,600	40,500	84,200	168,390	343,350	686,700	1,386,540	2,773,080
Contingency	6,890	15,660	46,460	96,690	193,390	394,310	788,630	1,592,350	3,184,680
COST FOR COVER	52,840	120,110	356,660	742,190	1,484,380	3,026,660	6,053,330	12,222,490	24,434,960
TOTAL ESTIMATED COST WITH COVER	436,250	641,810	1,219,160	1,850,510	3,217,760	5,528,920	10,095,150	18,384,960	34,840,260

A few storage facilities have been constructed, for which there are construction costs. Two projects for which a degree of comparison may be made include Cottage Farm (Cambridge [Boston], Massachusetts)(29) and Humbolt Avenue (Milwaukee, Wisconsin)(30).

Cottage Farm - The detention tanks at Cottage Farm have a very short detention time at the design flow (8 minutes). The pumping and screening facilities are the major cost associated with this project and separating the the cost associated with the "detention tanks" is an unpromising task; therefore, to check the cost correlation an attempt has been made to build-up the costs from the data presented in this report;

Item	Size	This Report Est.
Raw Wastewater Pumping	210 mgd (firm)	$ 8,300,000
Chlorination	-	100,000
Detention Basins	1.2 mg.	500,000
		8,900,000
Site Work	15% of subtotal	1,335,000
		$ 10,225,000

Actual Construction Cost mid-1969 - $4,852,000
EPA Index Inflation 1969-1975 = 1.73 x $4,852,000 = $8,400,000

Therefore, the estimate based on this report for the whole project is about 20 percent higher than inflating the original construction cost. This is considered good correlation since the actual cost must be inflated over an extended period of time.

Milwaukee - Humbolt Avenue - The 3.9 mg detention tank is estimated to cost $414,000 (July, 1969) exclusive of control building and other appurtenances (23). Inflating this cost to mid-1975 would result in a current estimated cost of about $720,000. The CWC report estimate indicates a cost of about $1,200,000 for a 3.9 mg detention tank.

Comparable construction costs should exist with large activated sludge aeration basins exclusive of aeration equipment. Nine uncovered activated sludge aeration basins were reviewed which ranged in size from 400,000 gallons to 5,000,000 gallons. Actual cost varied from 525,000 dollars per million gallons (0.4 mg size) to 308,000 dollars per million gallons (5.0 mg size). This report estimates for uncovered basins range from 383,400 dollars per million gallons (1.0 mg size) to 200,000 dollars per million gallons (5 mg size).

The comparisons made with cost data from other sources indicate that these estimates are reasonable and may be somewhat conservative.

Specific installations and general cost estimates were reviewed for the validity of the earthen reservoir costs. Chippewa Falls consists of an asphalt paved reservoir, pumping, and pipe facilities(24). No detailed cost data were available.

Two other estimating guides for earthen reservoirs are available. Black and Veatch(1) presented estimates for sludge lagoons ranging in size from about 225,000 gallons to 300 million gallons. Parker(25) presented cost estimates for lined and unlined ponds. The costs from these two sources and the estimates in this report are shown in the following tabulation:

Without Liner (Cost - Dollars)

Lagoon Volume (mg)	Black & Veatch*	Parker	This Report**
0.5	13,600	-	12,200
1.0	19,400	25,000	18,000
5.0	50,300	42,000	43,000
10.0	71,000	55,000	70,000
50.0	194,000	105,000	195,000
100.0	310,000	160,000	300,000
225.0	587,000	230,000	500,000

* Inflated in proportion to wage inflation - 1971-1975 (1.29x)
** Subtract liner cost from breakdown

With Liner (Cost - Dollars)

Lagoon Volume (mg)	Parker	CWC
1.0	-	30,000
5.0	89,000	88,000
10.0	130,000	150,000
50.0	400,000	520,000
100.0	700,000	900,000
225.0	1,500,000	1,800,000

The costs estimated in this report for earthen storage reservoirs, are comparable with previous estimates.

H. FLOCCULATION BASINS

The use of chemicals in combined sewer overflow treatment facilities has been investigated in conjunction with air flotation and sedimentation. The costs for the unit process of flocculation, independent of the chemical dosage or subsequent solids removal process is presented on the basis of basin volume and velocity gradient (G). The costs for flocculation basins are based on reinforced concrete basins and turbine type mixers used as flocculating devices.

A summary of the components of the facility costs are shown on Table 14 and are shown graphically on Figure 21.

TABLE 14

ESTIMATED CONSTRUCTION COSTS

FLOCCULATION BASINS

G = 70 hr^{-1}

Cost Component	Volume (Cubic Feet)					
	10,000	25,000	50,000	100,000	200,000	400,000
Manufactured Equipment	12,000	14,000	28,000	31,200	36,000	52,000
Concrete	3,430	6,010	9,940	16,020	24,840	51,900
Steel	9,960	11,060	18,220	27,100	40,070	72,120
Labor	13,120	20,740	36,590	49,500	71,880	129,400
Electrical	5,780	7,770	13,910	18,570	25,920	45,800
Miscellaneous Items	6,640	8,940	16,000	21,360	29,800	52,680
Contingency	7,640	10,280	18,400	24,560	34,280	60,590
TOTAL ESTIMATED COST	58,570	78,800	141,060	188,310	272,790	464,490

G - 110 hr^{-1}

Cost Component	Volume (Cubic Feet)					
	10,000	25,000	50,000	100,000	200,000	400,000
Manufactured Equipment	14,000	16,000	32,000	38,000	60,000	120,000
Concrete	3,430	6,010	9,940	16,020	24,840	51,900
Steel	9,960	11,060	18,220	27,100	40,070	72,120
Labor	13,820	21,440	37,990	51,880	80,280	153,200
Electrical	6,180	8,180	14,720	19,950	30,780	59,580
Miscellaneous Items	7,110	9,400	16,930	22,940	35,400	68,520
Contingency	8,180	10,810	19,470	26,380	40,710	78,800
TOTAL ESTIMATED COST	62,680	82,900	149,270	202,270	312,080	604,120

TABLE 14 (Continued)

$G = 150\ hr^{-1}$

Cost Component	Volume (Cubic Feet)					
	10,000	25,000	50,000	100,000	200,000	400,000
Manufactured Equipment	15,600	19,000	39,000	78,000	156,000	312,000
Concrete	3,430	6,010	9,940	16,020	24,840	51,900
Steel	9,960	11,060	18,220	27,100	40,070	72,120
Labor	14,380	22,490	40,440	65,880	107,880	194,400
Electrical	6,510	8,780	16,140	28,050	49,320	94,560
Miscellaneous Items	7,480	10,100	18,560	32,260	56,720	108,750
Contingency	8,600	11,620	21,350	37,100	65,220	125,060
TOTAL ESTIMATED COST	65,960	89,060	163,650	284,410	500,050	958,790

I. SEDIMENTATION BASINS

Costs for construction of plain sedimentation basins with sludge collection equipment have been presented in earlier cost studies(1). To provide updating of the previous information and to arrange the cost data in the format used in this study, the cost data from reference(1) were used as well as quantity takeoff information from several selected sedimentation basin sizes.

The cost data are presented as a function of the surface area provided, as was done in the earlier study. The basin depth will affect the cost of the sedimentation basin; albeit, minor variations will not exceed the accuracy of the estimate. The cost data presented have been based on a basin having a 12 feet side water depth and a 1.5 feet freeboard. Cost components are presented on the basis of steel troughs (launders) and weirs, which for the larger basins are more costly than single weir concrete troughs (launders), using current estimated unit prices. The costs are applicable to sedimentation basins using circular sludge collection equipment in circular basins. The costs are also applicable to larger basin complexes (greater than 20,000 square feet) using square or rectangular basins furnished with circular type sludge collection equipment. Cost data are not applicable to straight line sludge collection equipment in rectangular basins. Straight line sludge collection equipment and rectangular basins are estimated to cost from 15 to 20 percent more than the data presented in this study.

The cost components used in this study are presented on Table 15 and are summarized on Figure 22.

TABLE 15

ESTIMATED CONSTRUCTION COSTS

SEDIMENTATION BASINS

Cost Component	Surface Area (Square Feet)					
	5,006	10,000	20,800	45,400	90,800	136,200
Manufactured Equipment	59,400	101,200	128,550	275,000	550,000	825,000
Concrete	12,000	17,530	29,150	72,300	130,140	195,140
Steel	18,570	26,170	41,170	69,080	124,340	186,510
Labor	33,080	47,580	73,580	125,300	255,550	338,330
Miscellaneous Steel	21,600	47,800	140,800	284,620	512,320	768,480
Concrete Pipe	1,500	2,800	5,750	12,750	25,500	38,250
Electrical	21,920	43,960	62,850	125,860	235,180	352,760
Miscellaneous Items	25,210	50,550	72,280	144,740	270,450	405,670
Contingency	28,990	58,140	83,120	166,450	311,020	466,520
TOTAL ESTIMATED COST	222,270	445,730	637,250	1,276,100	2,384,500	3,576,660

J. CHEMICAL FEED EQUIPMENT AND STORAGE

There are many package systems available and many approaches to designing custom facilities for feeding and storage of chemicals. Also the many available forms of chemicals and chemical strengths make a general cost presentation on chemical feed systems difficult. Cost data for feeding frequently used chemicals are provided herein, based on the specific form of chemical described and are intended for general planning purposes only. For specific projects, it is necessary to describe and estimate the facility requirements in detail. Much of the cost data were derived from chemical feed system costs presented in the EPA Manual on Phosphorus Removal(26). The chemicals for which cost data are presented include the following:

	Capacity Range	Form	Storage
Lime	52 lb/hr	Hydrated Lime	15 days
	520-5200 lb/hr	Pebble Quicklime	15 days
Alum	65 lb/hr - 6600 lb/hr	Liquid (8.3% Al_2O_3)	15 days
Ferric Chloride	52 lb/hr - 5200 lb/hr	Liquid (35% $FeCl_3$)	15 days
Polymer	0.4 lb/hr - 35 lb/hr	Dry (0.25% Stock Solution)	15 days

1. Lime - The feed rate capacity is based on twice the average feed rate. Equipment for the smaller system includes two volumetric feeders with manually loaded bins, dissolving chambers and accessories. The larger than 50 pound per hour systems are based upon gravimetric feeder-slaker systems, steel storage bins flow and pH controls. A pneumatic unloading system is assumed, with a truck providing the blower.

2. Alum - Cost estimates are based on the use of liquid alum (8.3 percent Al_2O_3). For rates of 65 pounds per hour, alum feeding equipment includes two 25 gallon per hour hydraulic diaphragm pumps (one operating and one standby) with the necessary accessories and equipment to pace the feed rate with plant flow. Two 3,000 gallon fiberglass reinforced polyester (FRP) tanks with accessories are provided for storage of liquid alum. The total capacity of 6,000 gallons allows some flexibility in ordering and receiving 4,000 gallon tank truck shipments.

For rates of 660 pounds per hour, liquid alum is fed by three 125 gallons per hour rotodip-type feeders (two operating and one standby) with the necessary accessories and control panel for proportioning chemical feed to flow. Alum is stored in four 11,500 gallon FRP tanks.

For rates of 6,600 pounds per hour, liquid alum is fed with seven 415 gallons per hour rotodip-type feeders (six operating and one standby) with the necessary control equipment. Storage costs are based on ten 50,000 gallon underground concrete tanks with a rubber lining. The underground storage necessitates transfer pumps and day tanks for the rotodip feeders but eliminates the need for heating the tanks. Three 500 gallon FRP day tanks are included in the estimate; one for each pair of feeders. Four alum transfer pumps (three operating and one standby), with a capacity of 50 gallons per minute at 50 feet of head are provided.

The cost of feeding and storage facilities for the 6,600 pounds per hour rate is greater than 10 times the cost of facilities for the 660 pounds per hour rate. This is because underground storage facilities were the basis of design for the larger rate in contrast to FRP tanks located in an existing building for the lower rate. FRP tanks could be used for the larger plant, however, structural design may necessitate special construction requirements for underground FRP tanks. FRP tanks located above ground and on concrete foundations would require special insulation and heating.

3. Ferric Chloride - Costs of chemical storage and feeding equipment have been based on the use of liquid ferric chloride. Equipment similar to that described for liquid alum has been used as a basis. Ferric chloride in liquid form is about 4 pounds per gallon (based on 35 percent $FeCl_3$) as compared to about 5 pounds per gallon for alum (8.3 percent Al_2O_3).

4. Polymer - Cost estimates of solution preparation and feeding equipment have been prepared, based on the use of dry polymer. Chemical feed equipment was based on feed of a 0.25 percent stock solution. Piping and build-

ings to house the feeding equipment and store the bags are included.

Systems with less than 0.4 pounds per hour capacity were based on the polymer being manually fed to the mixing tank, with mixing and solution feed equipment arranged for manual control. Two independent systems of tanks and feeders are included. Systems for 3.5 pounds per hour include two volumetric dry feeders discharging to two mixing tanks, arranged for batch control. The mixing tanks discharge to a single holding tank from which two solution feeders take their supply for application to the process. The system for 35 pounds per hour includes four volumetric dry feeders complete with steel day hoppers, dust collectors, bin gates and flexible connectors. The system operation is automatic for the preparation and transfer of aged polymer solution from four mixing tanks to two holding tanks. Ten solution feeders meter the polymer to the treatment process.

An abbreviated cost breakdown is shown for the chemical feed and storage equipment on Table 16 and cost data are shown graphically in Figures 23 and 24.

TABLE 16

ESTIMATED CONSTRUCTION COSTS

CHEMICAL FEED SYSTEMS

Cost Component	Lime Feed (pounds per hour)		
	52	520	5200
Feeder & Storage Equipment	24,600	118,000	541,000
Housing	12,000	24,000	36,000
Electrical & Instrumentation	6,150	29,500	135,250
Miscellaneous Items	6,410	25,720	106,840
Contingency	7,370	29,580	122,860
TOTAL ESTIMATED COST	56,530	226,800	941,950

Cost Component	Coagulant Feed (pounds per hour)		
Alum	66	660	6600
Ferric	52	520	5200
Feeder & Storage Equipment	19,000	60,000	628,000
Housing	3,000	9,000	18,000
Electrical & Instrumentation	4,750	15,000	157,000
Miscellaneous Items	4,010	12,600	120,450
Contingency	4,610	14,490	138,520
TOTAL ESTIMATED COST	35,370	111,090	1,061,970

Cost Component	Polymer Feed (pounds per hour)		
	0.4	3.5	35
Feeder & Storage Equipment	7,400	34,000	258,000
Housing	3,000	6,000	24,000
Electrical & Instrumentation	1,850	8,500	64,500
Miscellaneous Items	1,840	7,280	51,980
Contingency	2,110	8,370	59,770
TOTAL ESTIMATED COST	16,200	64,150	458,250

K. RAW WASTEWATER PUMPING

Costs for raw wastewater pumping were presented in the previously referenced cost study(1). This study updates those costs and identifies cost components. Raw wastewater pumping cost data are based on a facility which includes rough screening facilities and a wet well separated from a dry well which houses the pumps and piping. A superstructure housing electrical control equipment and surface access is provided. The station capacity refers to the firm pumping capacity based on all pumping units operating except the largest unit.

The pumping station depth influences the cost of the structure; however, it is an unusual structure which exceeds 35 to 40 feet in depth, and special estimating procedures should be used in those specific cases. Costs for dewatering, cofferdams, and rock excavation are not included and are often encountered. For general planning purposes these cost data should be increased an additional 10 percent to provide for average subsurface conditions encountered for sewage pumping stations. For specific projects, information should be obtained regarding subsurface conditions because the costs to overcome adverse conditions may well exceed the previously stated allowance.

Since the earlier study on costs, several requirements have been imposed on design which have increased typical station costs. These requirements include safety provisions (OSHA) and more reliable electrical service (2 independent feeders) or other equally reliable facilities. The OSHA provisions have not affected the facilities provided so much as the construction methods used. The increased electrical service requirements directly affect the cost of the facility. Therefore, the cost increase since the previously prepared study(1) is more than inflation indices would indicate. Provisions for these additional requirements have been made in the cost data presented.

The cost components for raw sewage pumping stations are presented in Table 17 and the estimated construction costs are summarized on Figure 25.

TABLE 17

ESTIMATED CONSTRUCTION COSTS

RAW WASTEWATER PUMPING

Cost Component	Firm Pumping Capacity (million gallons per day)					
	1	10	20	50	100	200
Manufactured Equipment	26,400	129,600	230,400	480,000	864,000	1,540,000
Concrete	6,600	32,400	57,600	120,000	216,000	385,000
Steel	13,200	64,800	115,200	240,000	432,000	770,000
Labor	26,400	129,600	230,400	480,000	864,000	1,540,000
Metal Pipe and Valves	7,900	38,880	69,120	144,000	259,200	462,000
Concrete Pipe	-	-	-	-	-	-
Housing	4,000	19,400	34,560	72,000	129,600	231,000
Electrical and Instrumentation	19,800	97,200	172,800	360,000	648,000	1,155,000
Miscellaneous Items	15,650	76,780	136,510	284,400	511,920	912,450
Contingency	17,990	88,300	156,990	327,060	588,710	1,049,320
TOTAL ESTIMATED COST	137,940	676,960	1,203,580	2,507,460	4,513,430	8,044,770

L. SLUDGE PUMPING STATIONS

Sludge pumping stations are required in specific stormwater treatment facilities where gravity return to the dry weather sewer is not possible. Sludge pumping equipment is selected based on the sludge concentration to be pumped and the operation intended. Sludge pumping units which operate continuously may be centrifugal pumps, so long as one avoids high solids concentrations and large suction head losses. For sludges which compact to high concentration and intermittent sludge pumping, positive displacement pumps are generally used. Positive displacement pumping units are more expensive than equal capacity centrifugal pumping units. If centrifugal type pumping units are used, the sludge or concentrate pumping station will be less expensive and these cost data are not applicable. Centrifugal type pumping units might be used for continuous pumping and in specific cases have been used with the cyclonic degritters.

The cost data presented in the earlier study(1) were based on positive displacement pumping units. This study updates those costs and identifies cost components.

The station is based on an underground structure housing pumping units and piping, constructed adjacent to and in conjunction with the solids separation unit process. A superstructure is included to access the station from the ground level and to house electrical control equipment. Cost components are presented in Table 18 and the current estimated construction costs are summarized on Figure 26.

TABLE 18

ESTIMATED CONSTRUCTION COSTS

SLUDGE PUMPING STATIONS

Cost Component	Firm Pumping Capacity (gallons per minute)						
	50	100	200	500	1,000	2,000	5,000
Manufactured Equipment	6,710	9,680	14,300	22,000	30,800	44,000	68,200
Concrete	1,220	1,760	2,600	4,000	5,600	8,000	12,400
Steel	3,660	5,280	7,800	12,000	16,800	24,000	37,200
Labor	12,200	17,600	26,000	40,000	56,000	80,000	124,000
Metal Pipe and Valves	7,320	10,560	15,600	24,000	33,600	48,000	74,400
Housing	7,930	11,440	16,900	26,000	36,400	52,000	80,600
Electrical and Instrumentation	7,810	11,260	16,640	25,600	35,840	51,200	79,360
Miscellaneous Items	7,030	10,140	14,980	23,040	32,260	46,080	71,420
Contingency	8,080	11,660	17,220	26,500	37,100	52,990	82,140
TOTAL ESTIMATED COST	61,960	89,380	132,040	203,140	284,400	406,270	629,720

M. FLOW MEASUREMENT

Flow measurement should always be provided in the treatment process train. The flow measurement device is normally constructed in conjunction with other structures. The most common wastewater measurement device is the venturi flume. Variations include the Parshall flume and Palmer Bowlus flume. Cost differences will exist, albeit the variation will be difficult to identify in total project construction costs.

The flume is normally constructed without a housing for the flume, and a differential cell and transmitter is provided to record the flow at a centrally located instrument panel.

The cost data are based on reinforced concrete construction and a flume length four times longer than the throat width. A riser well preceding the inlet channel and a drop channel following the channel is included in the costs. The flume section is provided with a premolded fiberglass flume.

Cost components are presented on Table 19 and current estimated construction costs are shown graphically on Figure 27.

TABLE 19

ESTIMATED CONSTRUCTION COSTS

OPEN CHANNEL VENTURI FLUME

Cost Component	Flow Rate (million gallons per day)					
	10	40	70	90	130	230
Manufactured Equipment	1,600	3,600	6,000	8,000	10,000	12,000
Concrete	500	800	1,000	1,400	2,000	2,600
Steel	1,000	2,000	3,000	4,000	6,000	8,000
Labor	1,200	2,400	3,000	4,000	6,000	8,000
Instrumentation	3,600	3,600	3,600	3,600	3,600	3,600
Miscellaneous Items	1,200	1,860	2,500	3,150	4,140	5,130
Contingency	1,370	2,140	2,870	3,620	4,760	5,900
TOTAL ESTIMATED COST	10,470	16,400	21,970	27,770	36,500	45,230

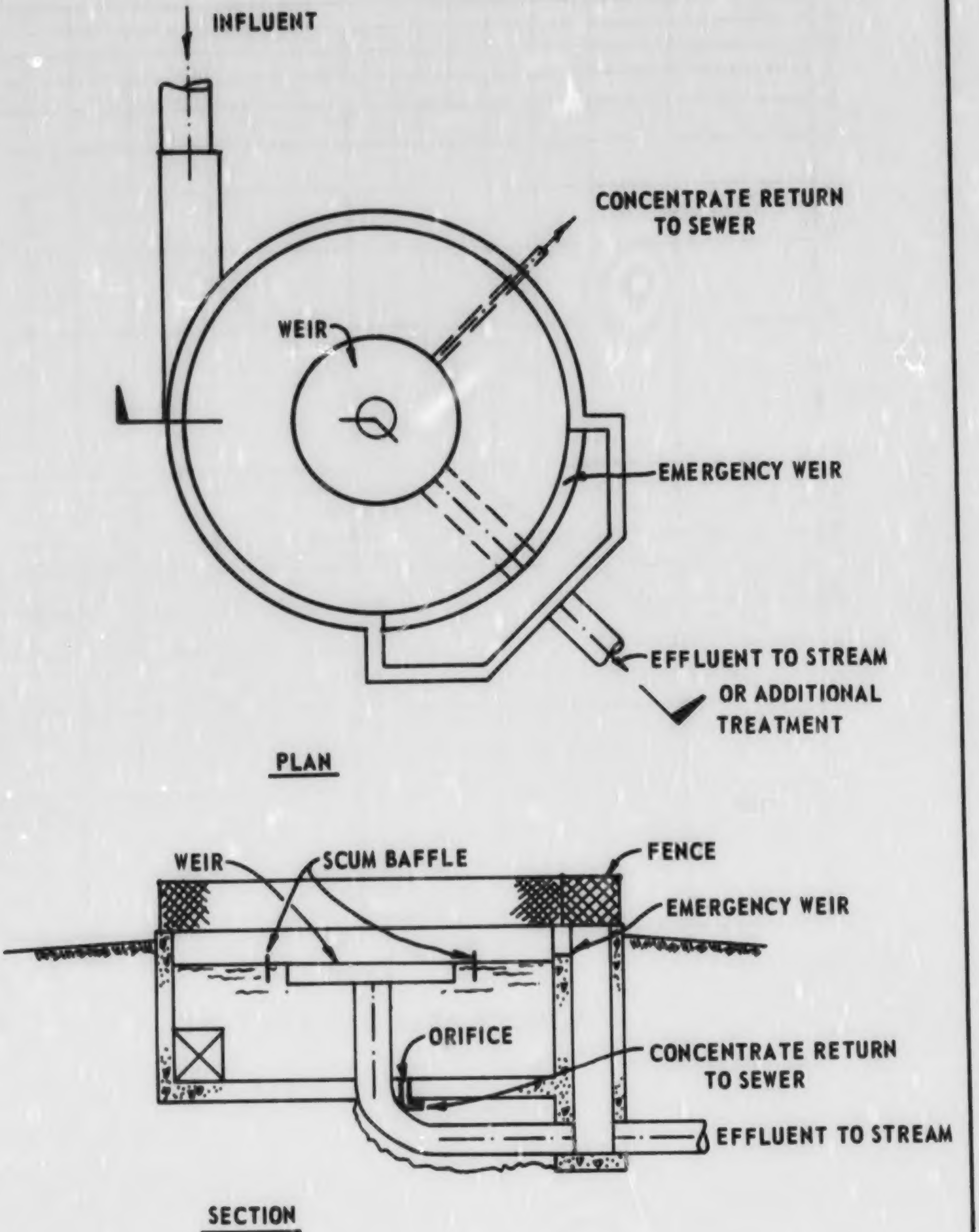

INFLUENT
CONCENTRATE RETURN TO SEWER
WEIR
EMERGENCY WEIR
EFFLUENT TO STREAM OR ADDITIONAL TREATMENT
PLAN
WEIR
SCUM BAFFLE
FENCE
EMERGENCY WEIR
ORIFICE
CONCENTRATE RETURN TO SEWER
EFFLUENT TO STREAM
SECTION

FIGURE 1 SWIRL OVERFLOW REGULATOR/CONCENTRATOR LAYOUT

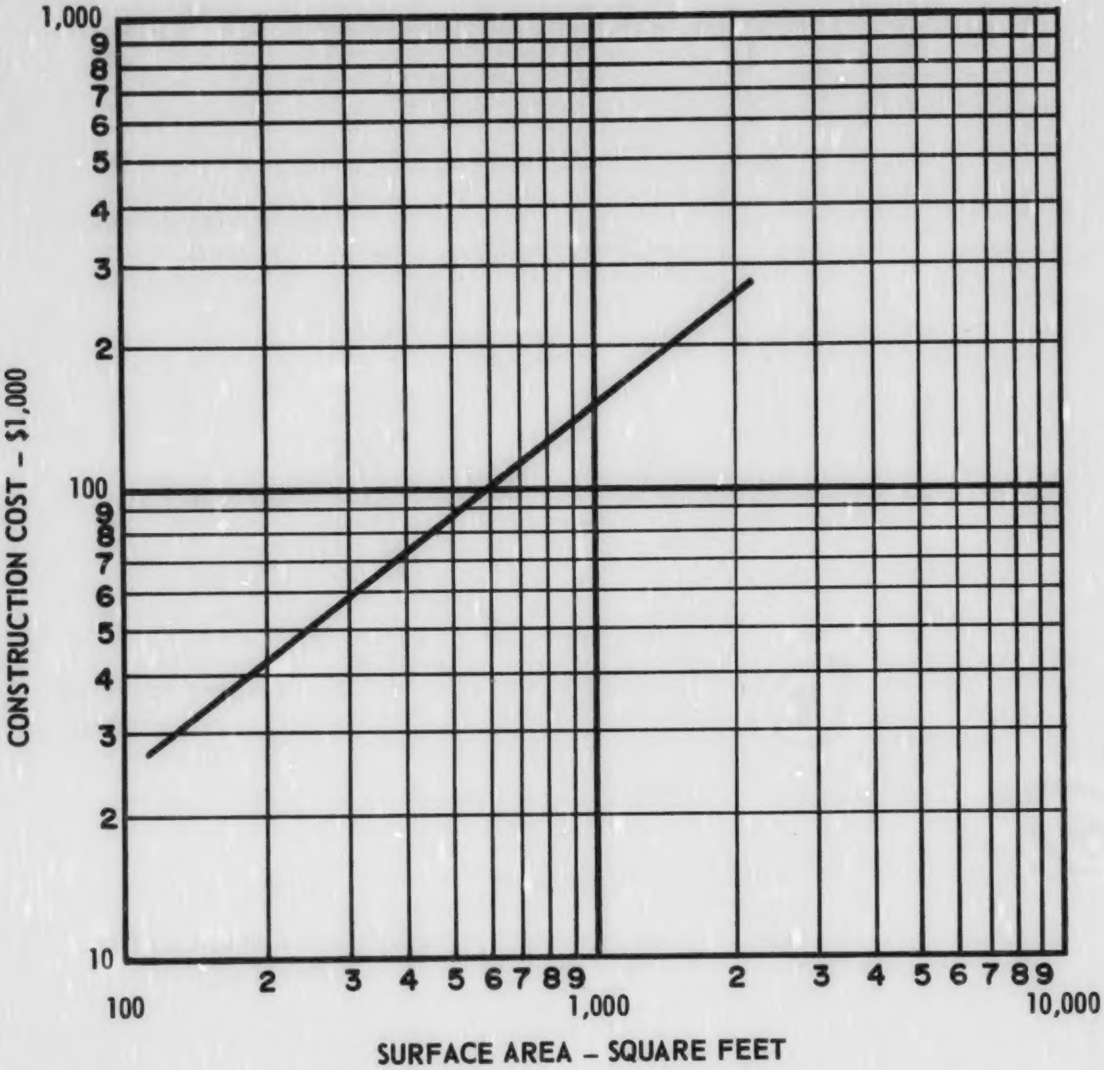


FIGURE 2 – SWIRL OVERFLOW REGULATOR/CONCENTRATOR – COST

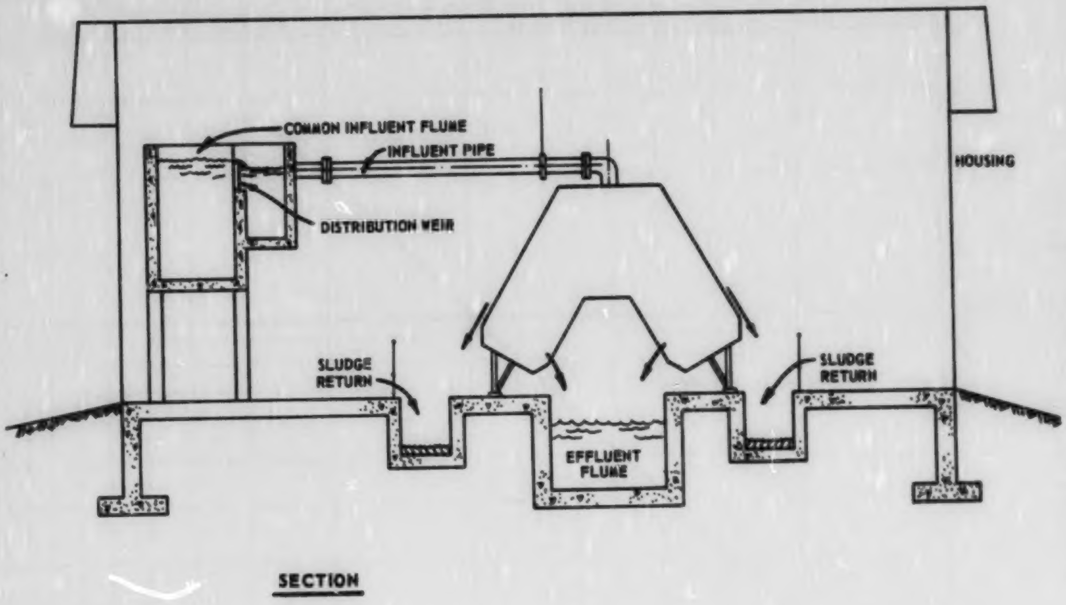

COMMON INFLUENT FLUME
INFLUENT PIPE
HOUSING
DISTRIBUTION WEIR
SLUDGE RETURN
SLUDGE RETURN
EFFLUENT FLUME
SECTION

FIGURE 3 STATIONARY SCREEN – LAYOUT

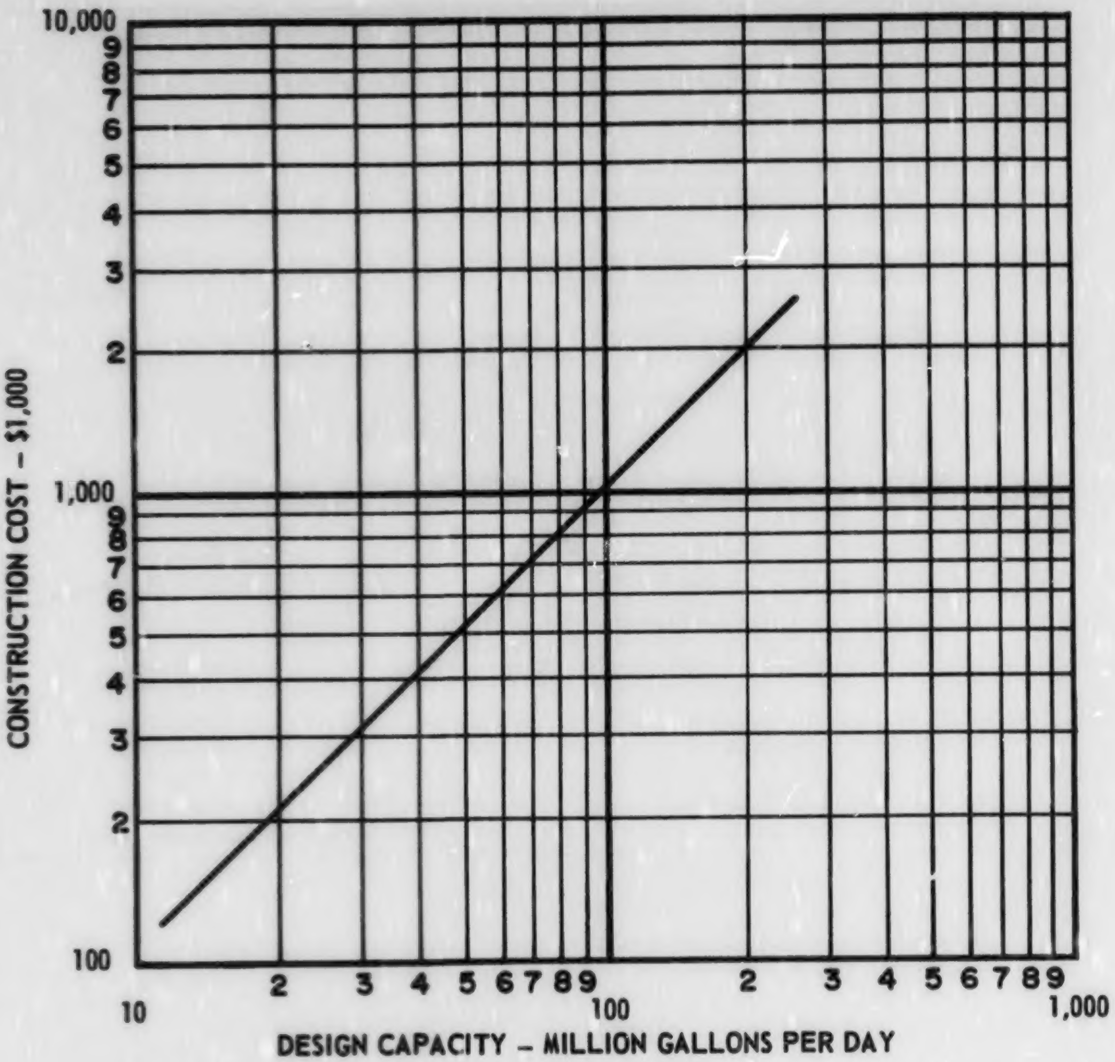


FIGURE 4 – STATIONARY SCREEN – COST

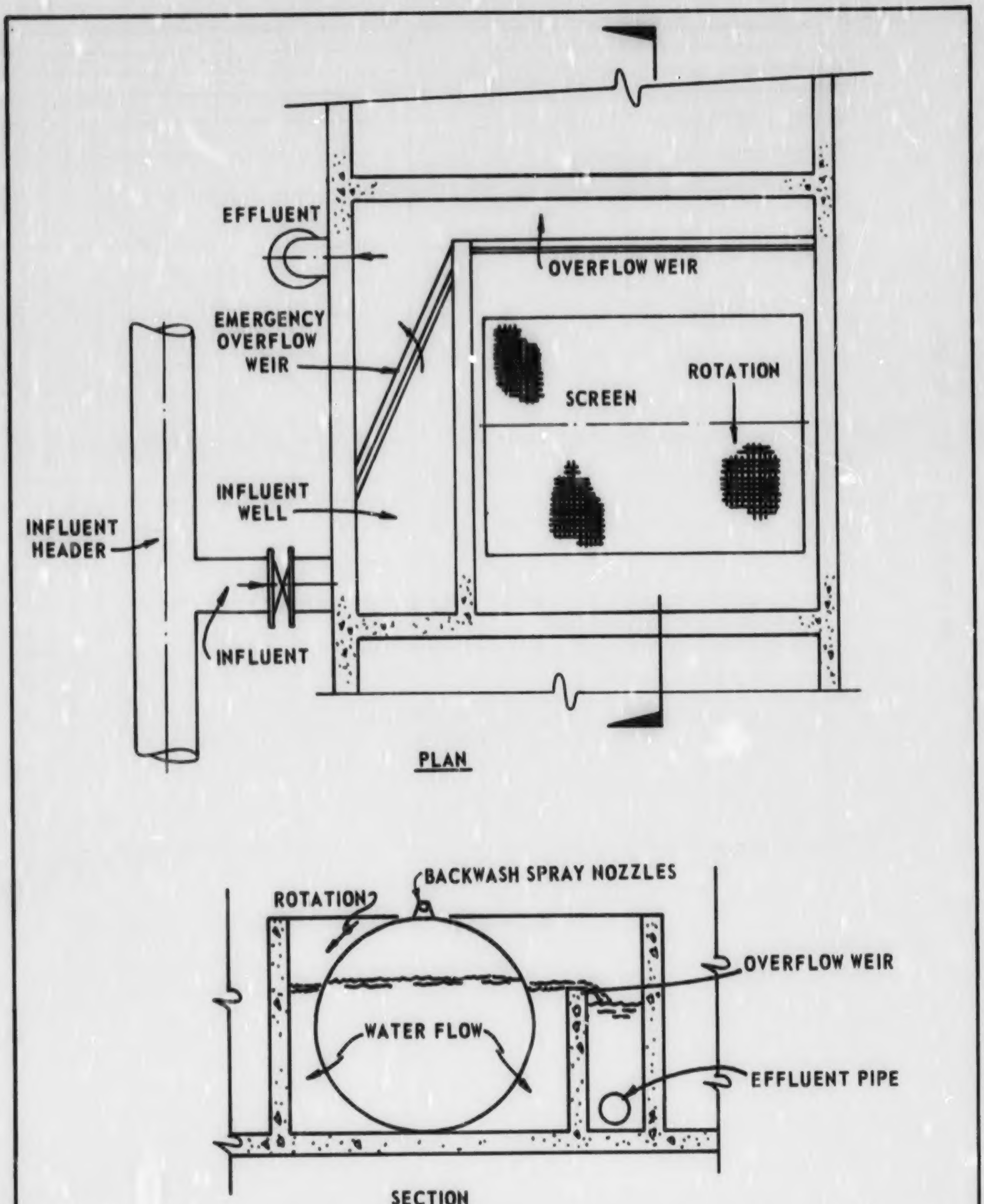

EFFLUENT
OVERFLOW WEIR
EMERGENCY OVERFLOW WEIR
ROTATION
SCREEN
INFLUENT WELL
INFLUENT HEADER
INFLUENT
PLAN
BACKWASH SPRAY NOZZLES
ROTATION
OVERFLOW WEIR
WATER FLOW
EFFLUENT PIPE
SECTION

FIGURE 5 HORIZONTAL SHAFT ROTARY SCREEN LAYOUT

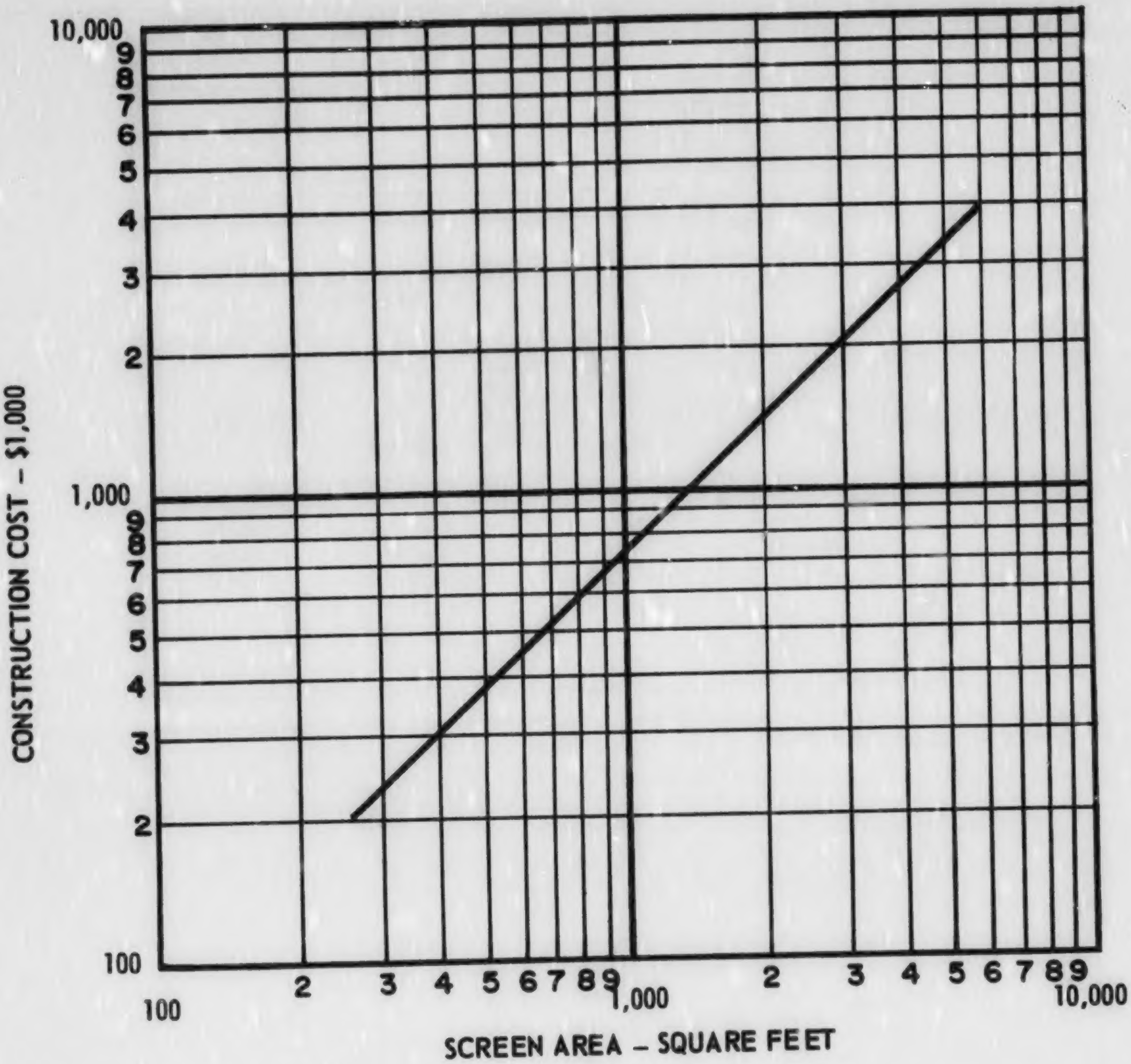
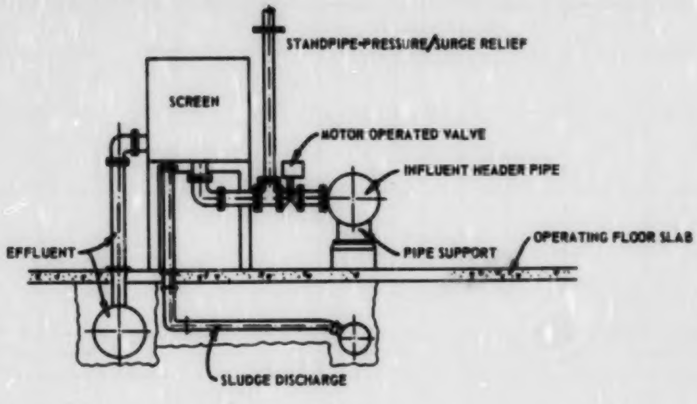
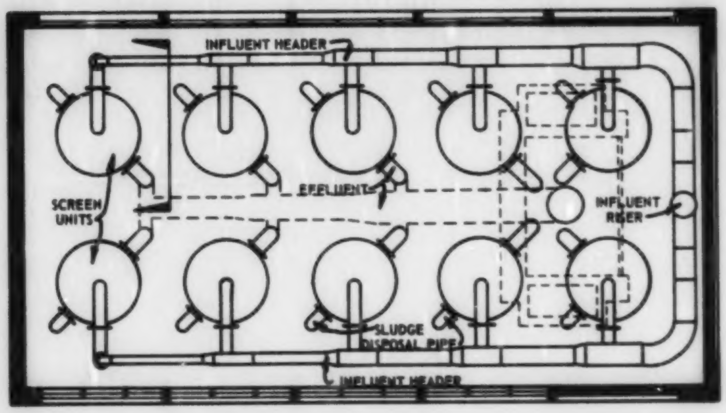


FIGURE 6 – HORIZONTAL SHAFT ROTARY SCREEN – COST


STANDPIPE-PRESSURE/SURGE RELIEF
SCREEN
MOTOR OPERATED VALVE
INFLUENT HEADER PIPE
EFFLUENT
PIPE SUPPORT
OPERATING FLOOR SLAB
SLUDGE DISCHARGE

SECTION


INFLUENT HEADER
EFFLUENT
SCREEN UNITS
INFLUENT RISER
SLUDGE DISPOSAL PIPE
INFLUENT HEADER

PLAN

FIGURE 7 VERTICAL SHAFT ROTARY SCREEN

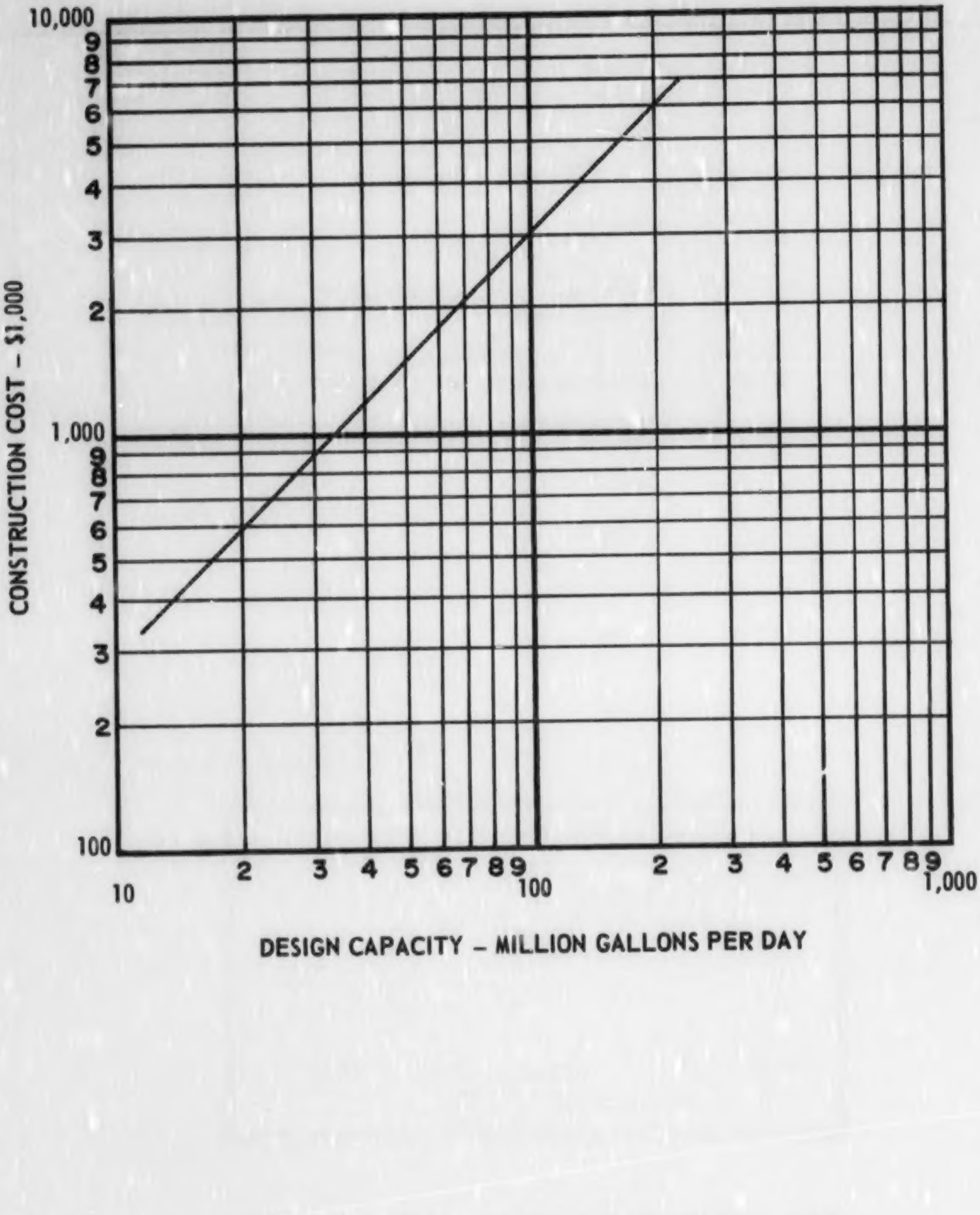
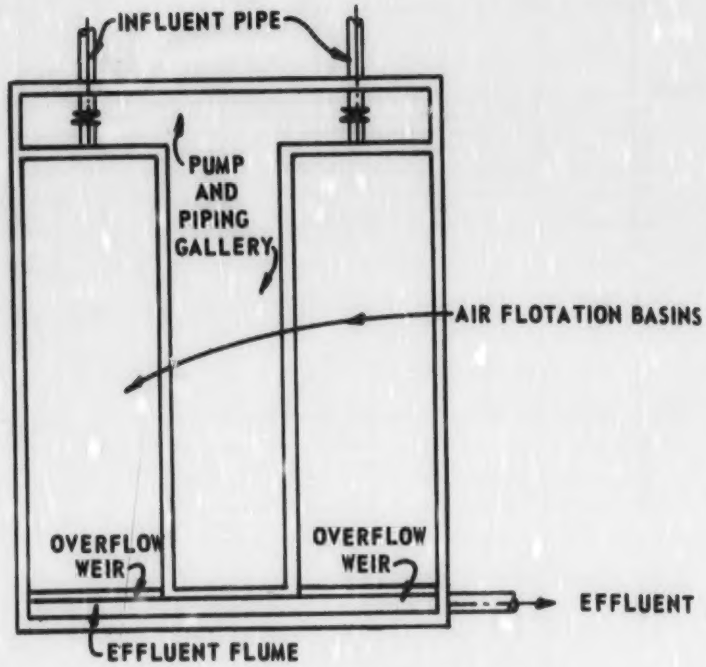


FIGURE 8 – VERTICAL SHAFT ROTARY SCREEN – COST


INFLUENT PIPE
PUMP AND PIPING GALLERY
AIR FLOTATION BASINS
OVERFLOW WEIR
OVERFLOW WEIR
EFFLUENT
EFFLUENT FLUME

SECTIONAL PLAN

FIGURE 9 AIR FLOTATION – LAYOUT

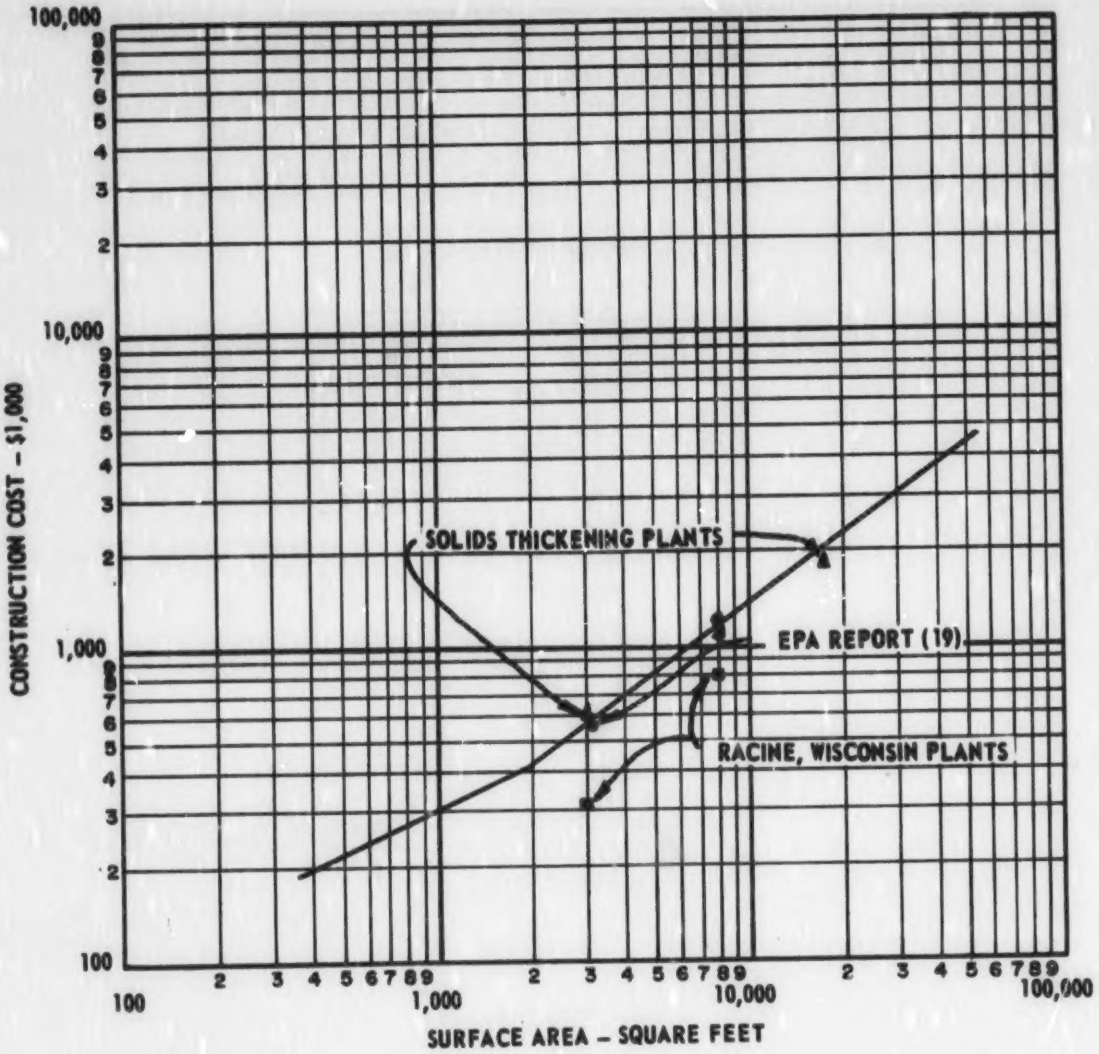


FIGURE 10 – AIR FLOTATION – COST

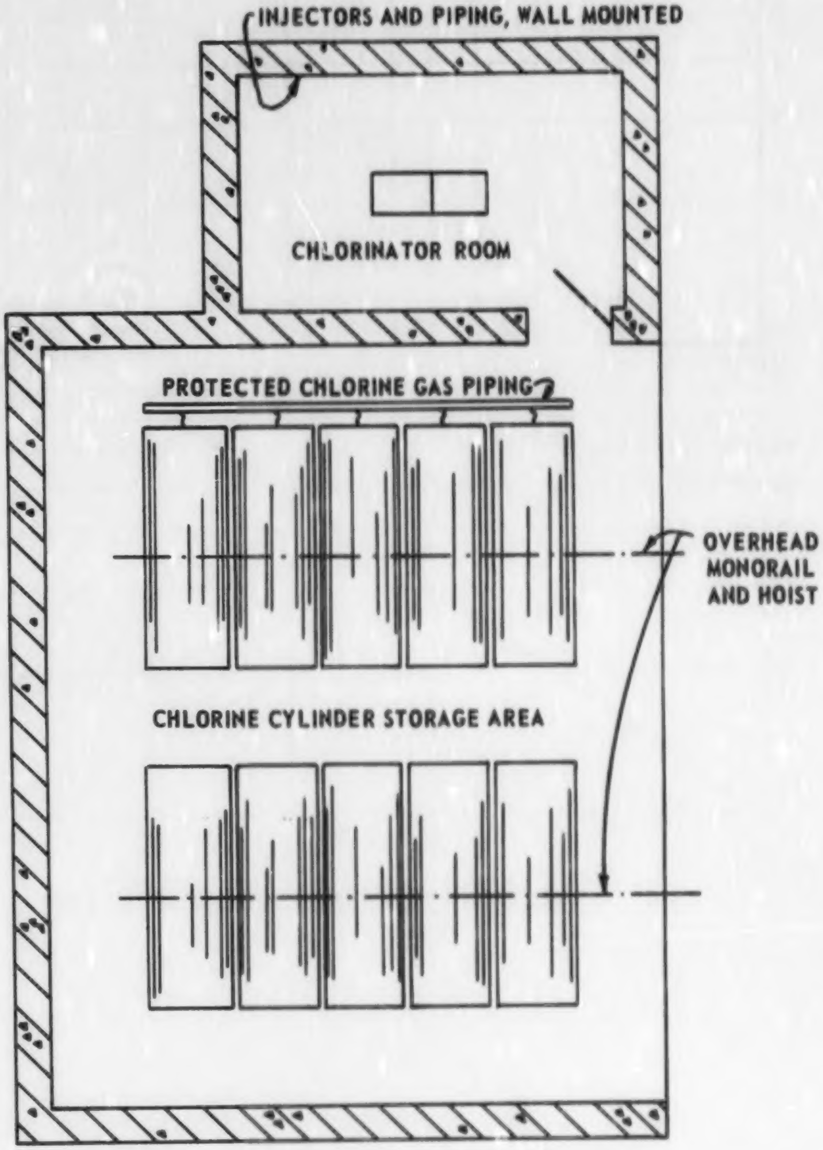

INJECTORS AND PIPING, WALL MOUNTED
CHLORINATOR ROOM
PROTECTED CHLORINE GAS PIPING
OVERHEAD
MONORAIL
AND HOIST
CHLORINE CYLINDER STORAGE AREA

FIGURE 11 CHLORINE (GAS) – LAYOUT

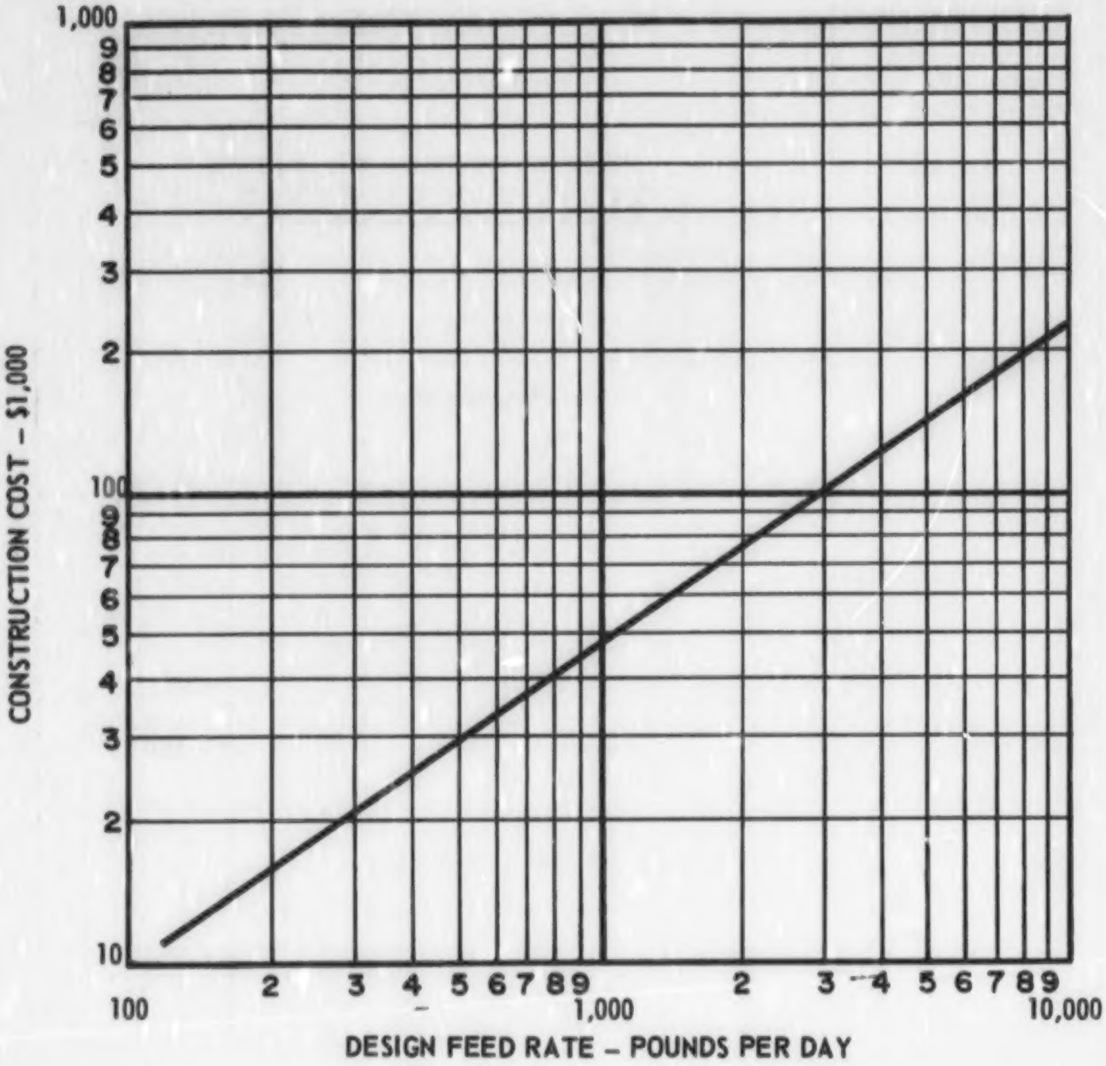


FIGURE 12 – CHLORINE (GAS) – COST

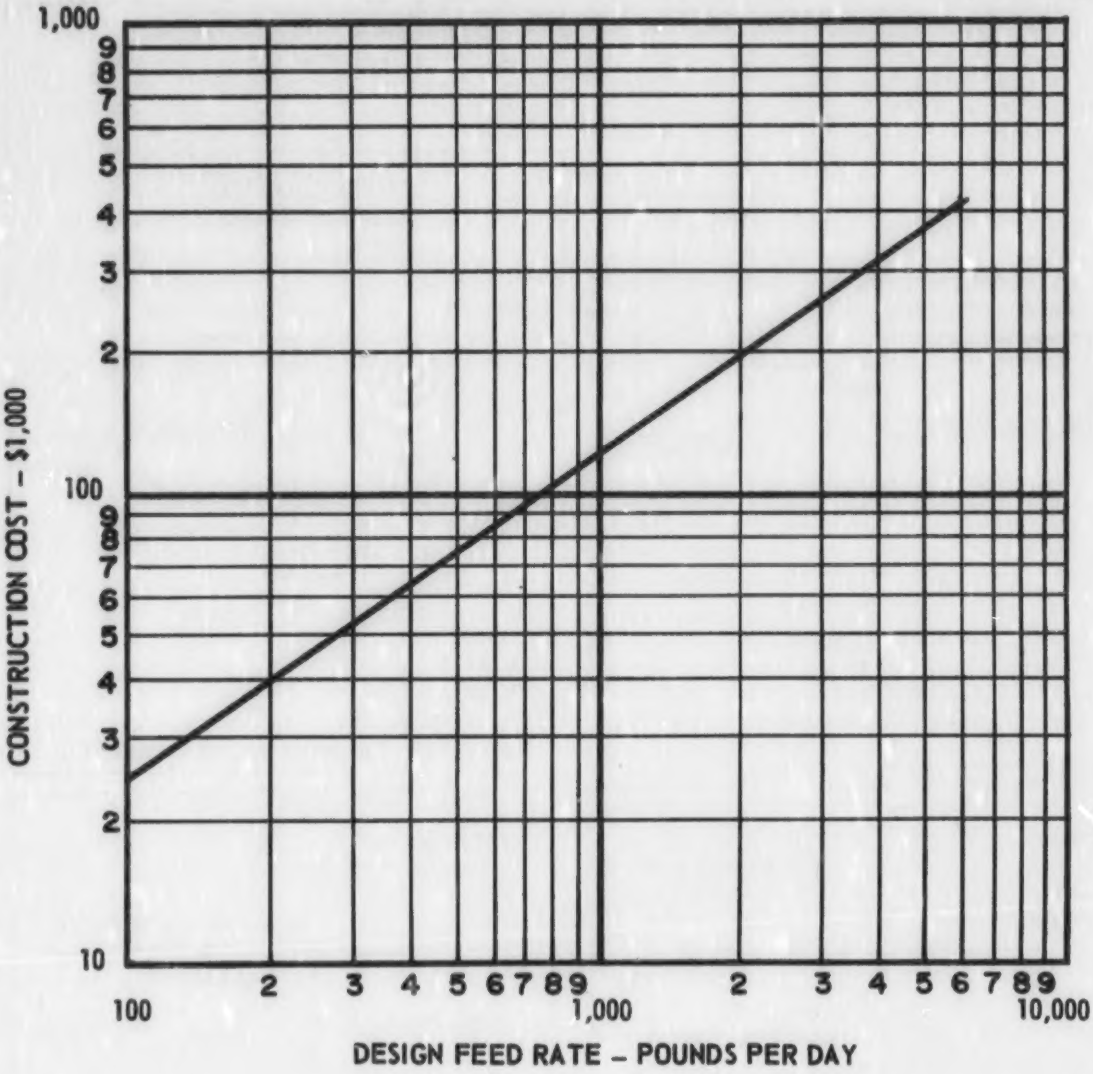


FIGURE 14 – CHLORINE DIOXIDE – COST

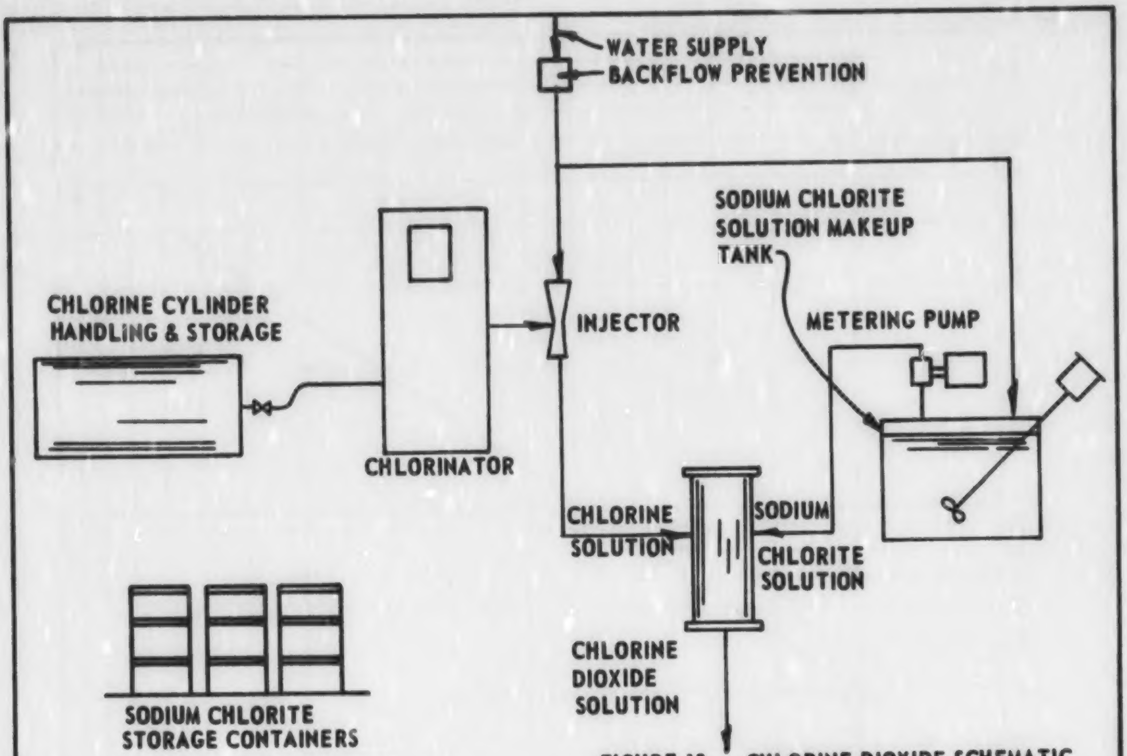

WATER SUPPLY
BACKFLOW PREVENTION
SODIUM CHLORITE SOLUTION MAKEUP TANK
CHLORINE CYLINDER HANDLING & STORAGE
INJECTOR
METERING PUMP
CHLORINATOR
CHLORINE SOLUTION
SODIUM CHLORITE SOLUTION
CHLORINE DIOXIDE SOLUTION
SODIUM CHLORITE STORAGE CONTAINERS

FIGURE 13 CHLORINE DIOXIDE SCHEMATIC

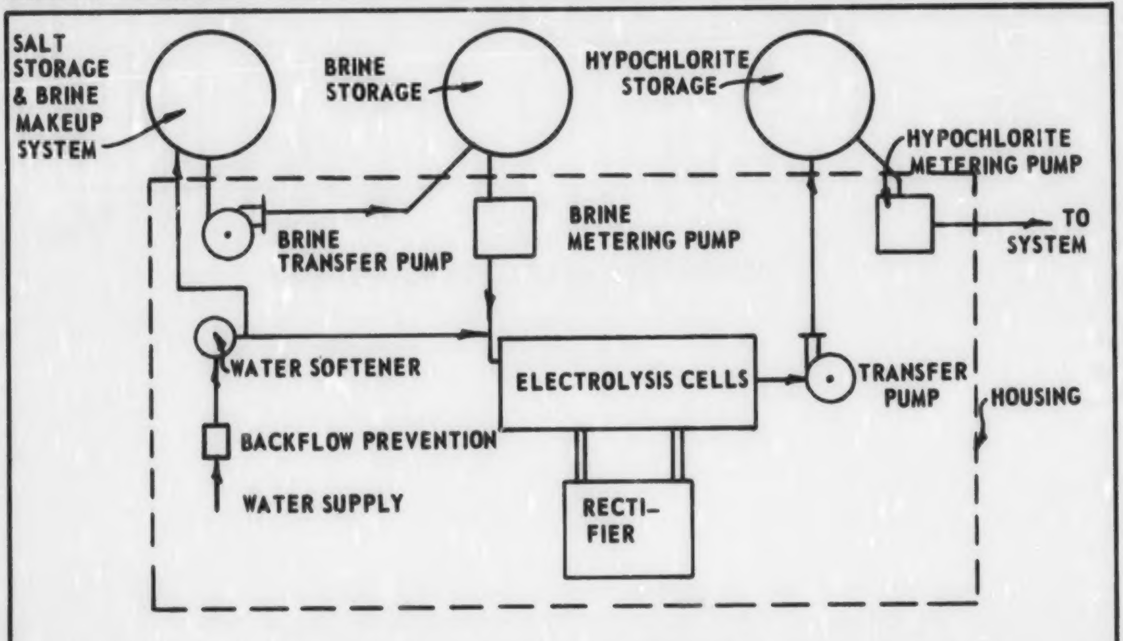

SALT STORAGE & BRINE MAKEUP SYSTEM
BRINE STORAGE
HYPOCHLORITE STORAGE
HYPOCHLORITE METERING PUMP
BRINE METERING PUMP
TO SYSTEM
BRINE TRANSFER PUMP
WATER SOFTENER
ELECTROLYSIS CELLS
TRANSFER PUMP
HOUSING
BACKFLOW PREVENTION
WATER SUPPLY
RECTI-FIER

FIGURE 15 HYPOCHLORITE GENERATION SCHEMATIC

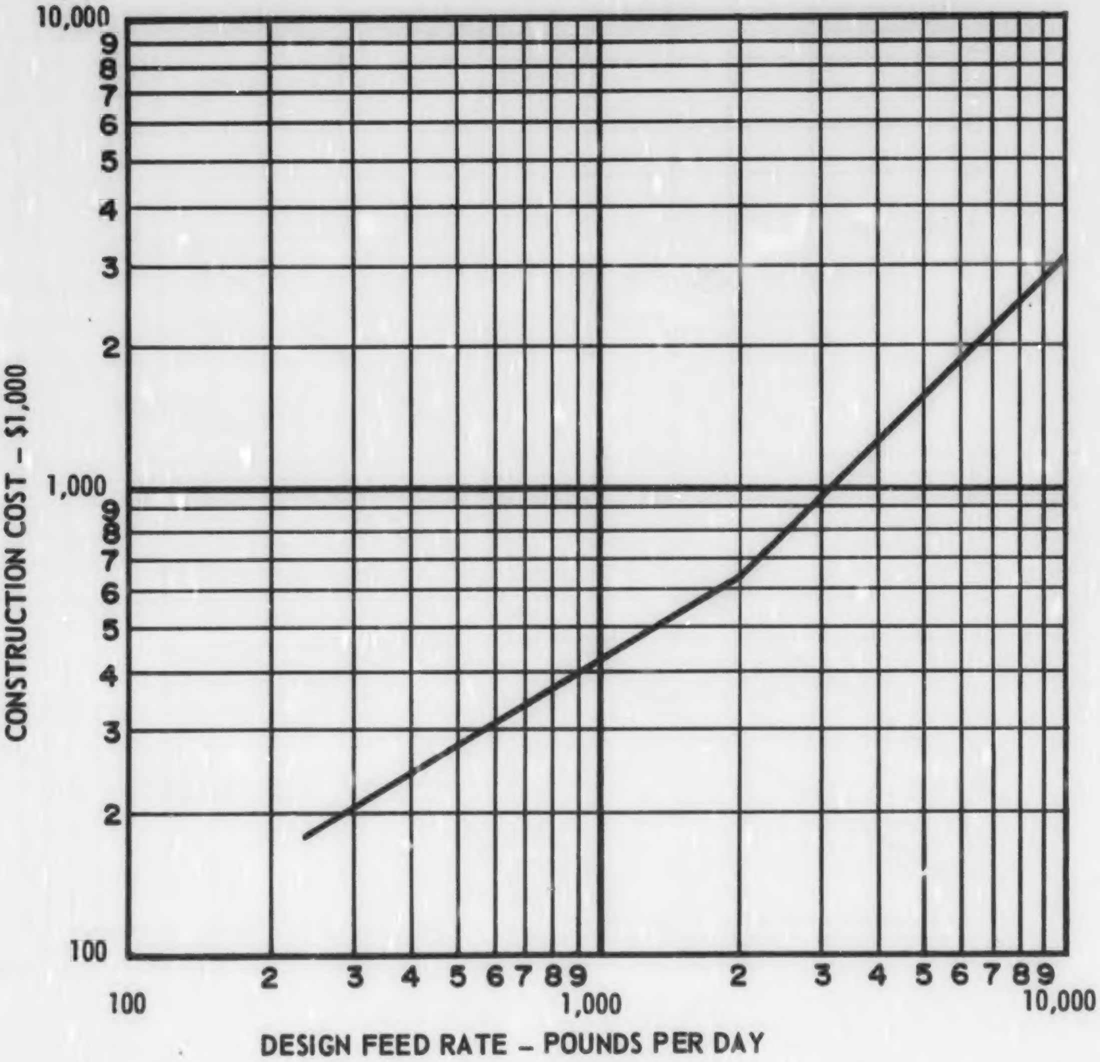


FIGURE 16 – HYPOCHLORITE GENERATION – COST

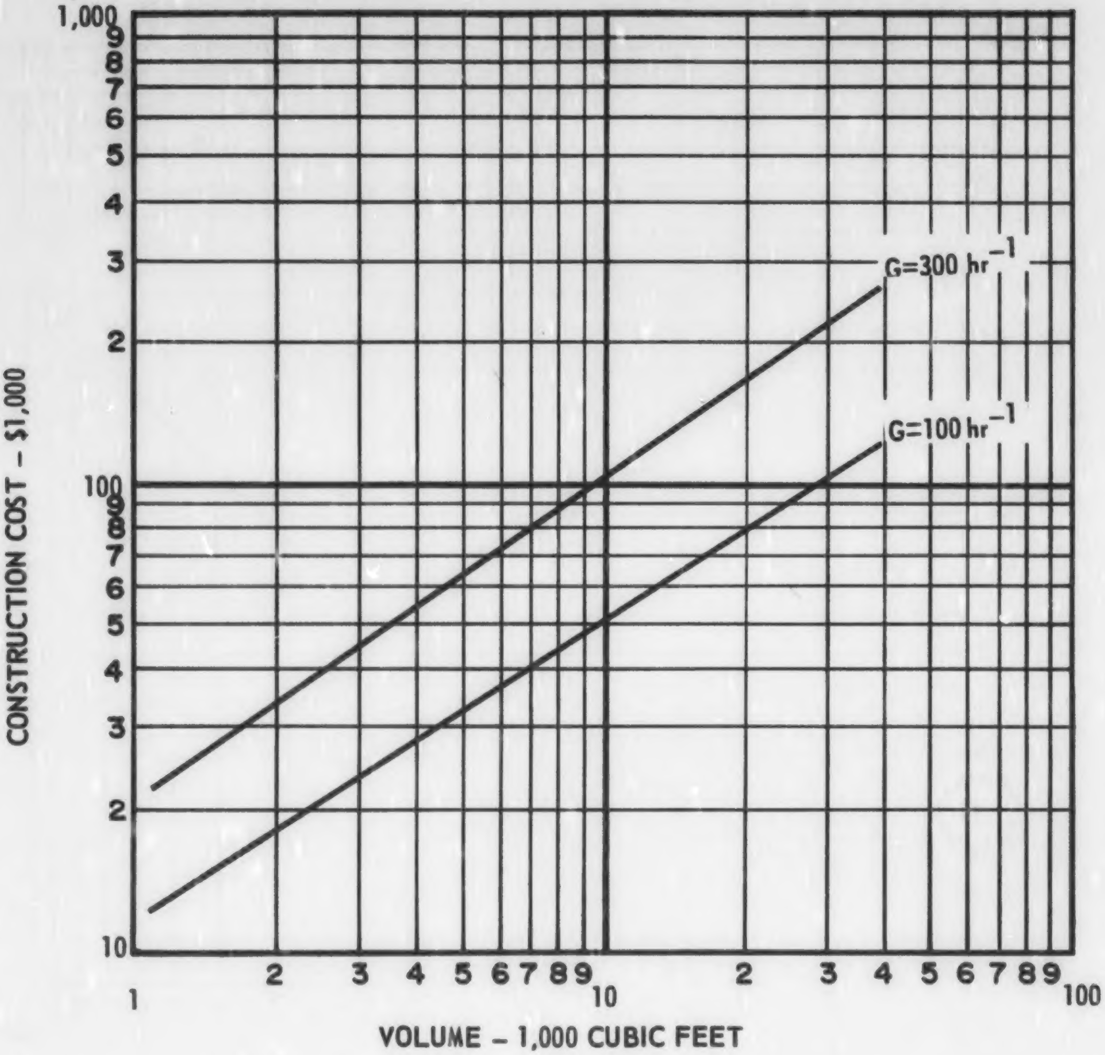


FIGURE 17 – HIGH INTENSITY MIXING/CHLORINE CONTACT BASIN – COST

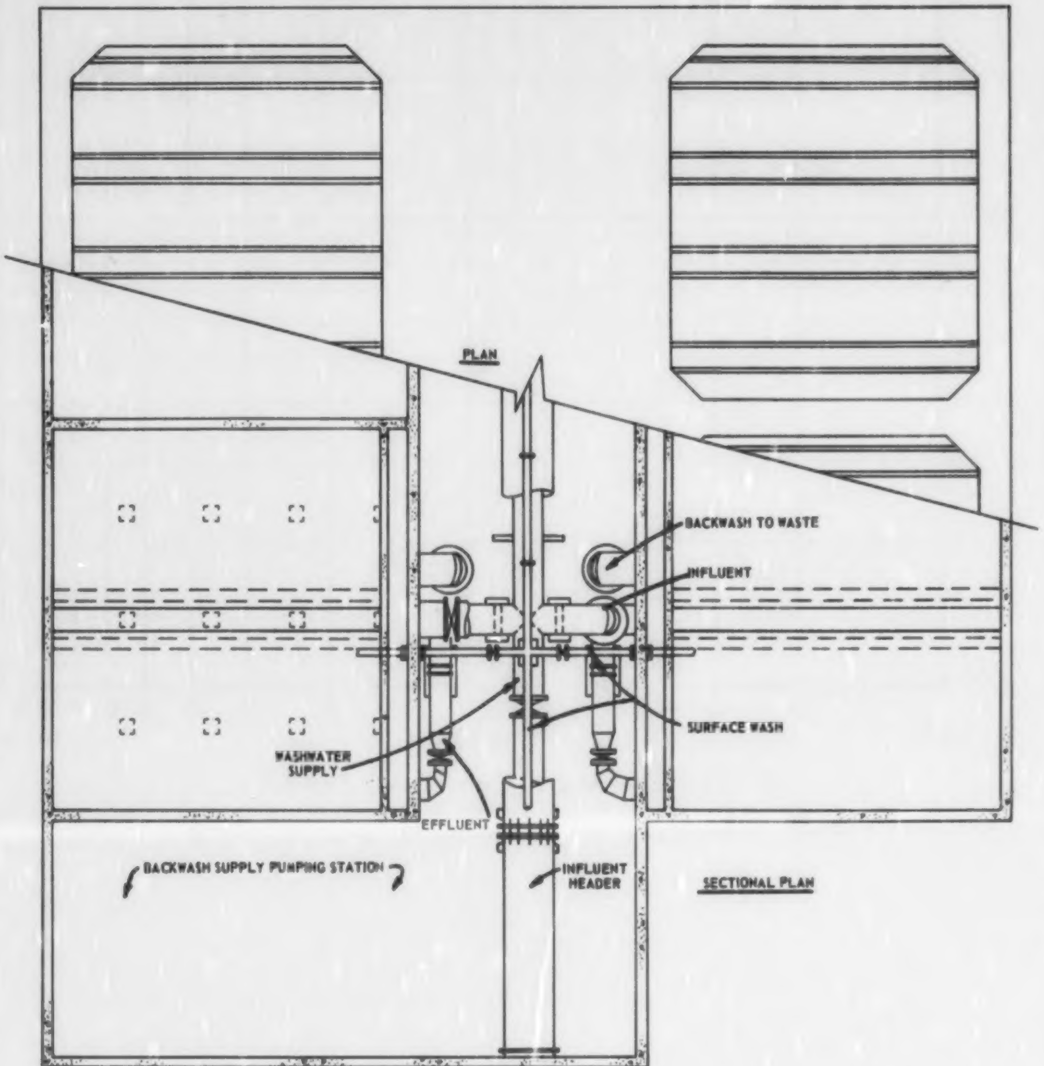

PLAN
BACKWASH TO WASTE
INFLUENT
SURFACE WASH
WASHWATER SUPPLY
EFFLUENT
BACKWASH SUPPLY PUMPING STATION
INFLUENT HEADER
SECTIONAL PLAN

FIGURE 18 FILTRATION – LAYOUT

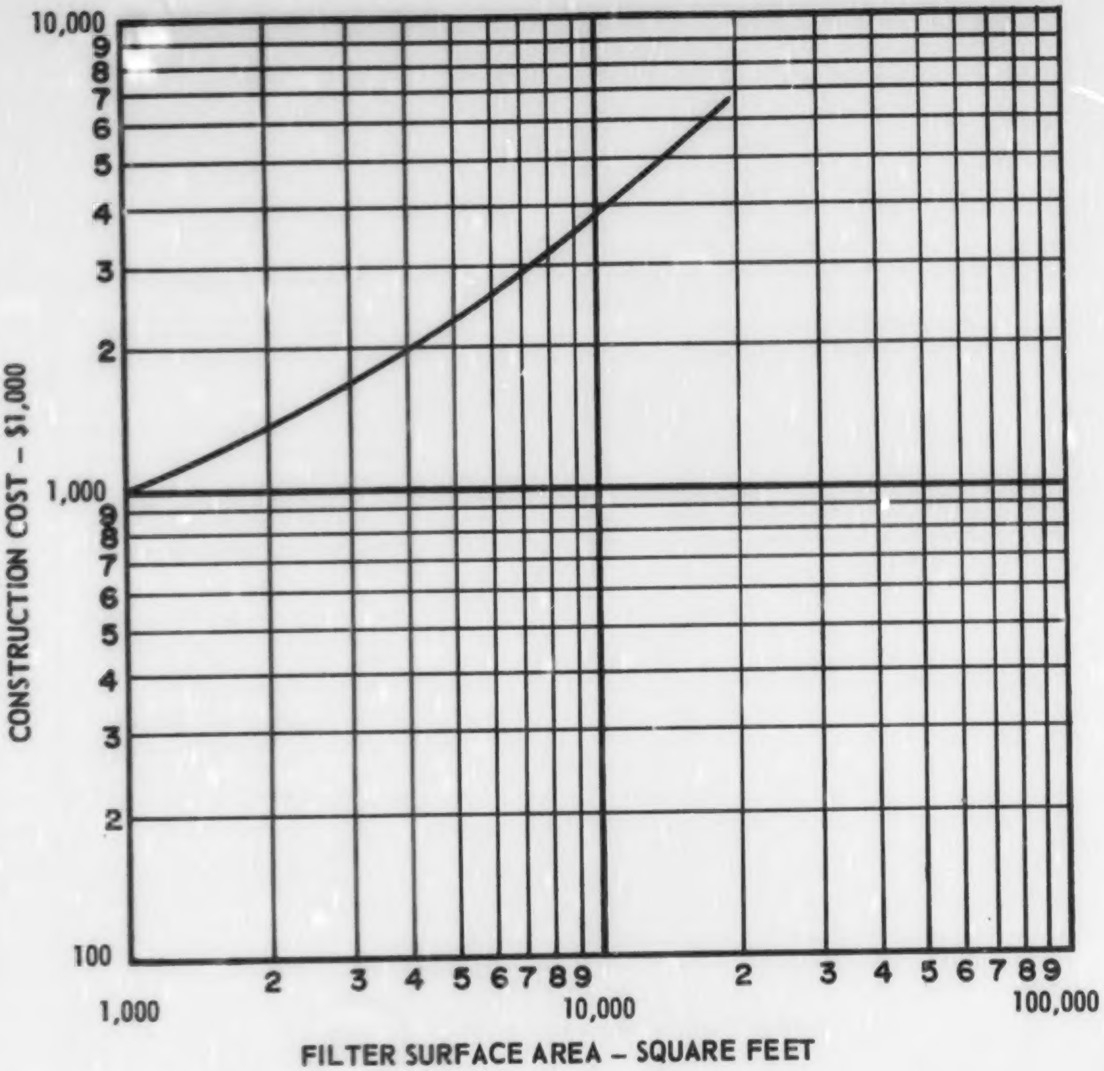


FIGURE 19 – FILTRATION – COST

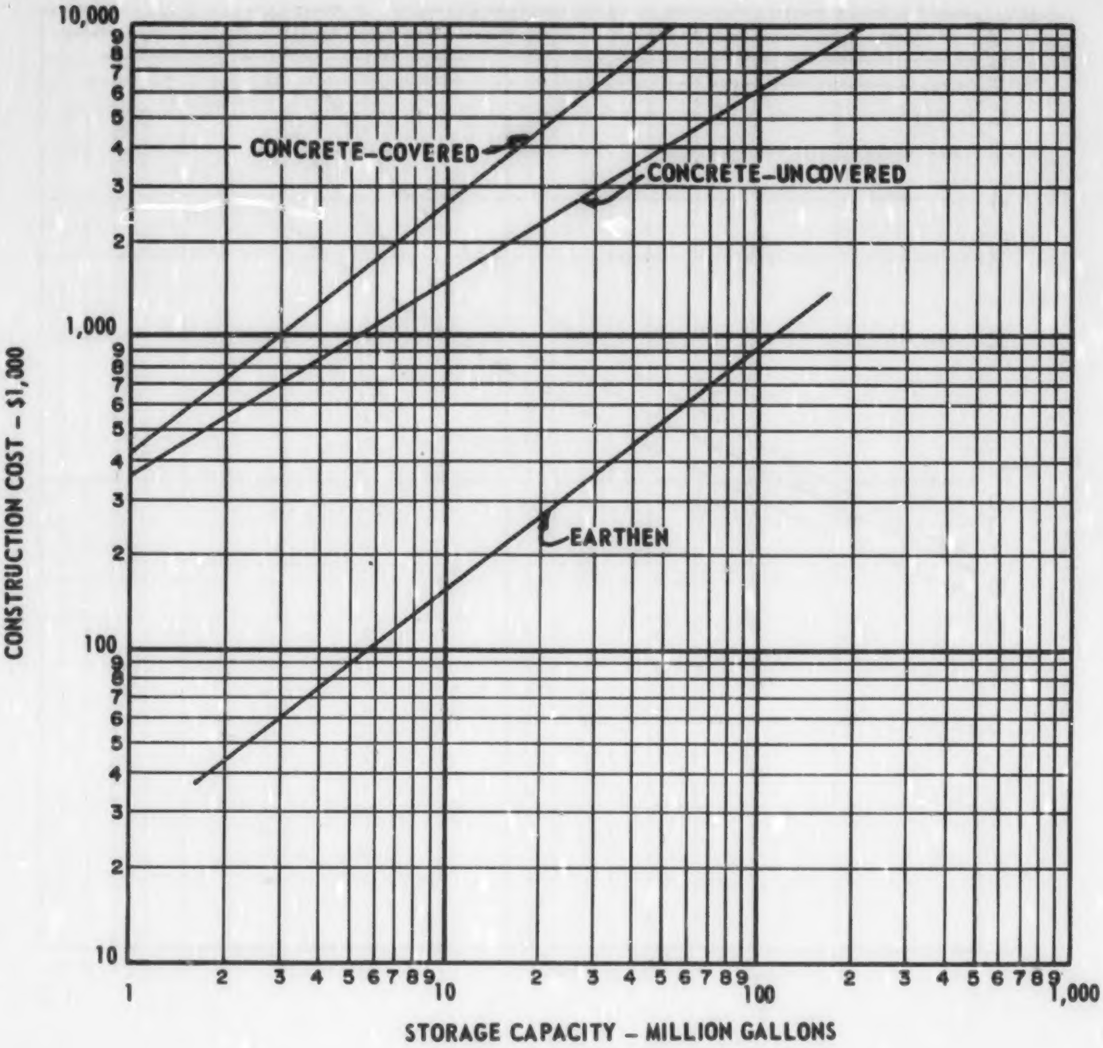


FIGURE 20 – STORAGE RESERVOIR – COST

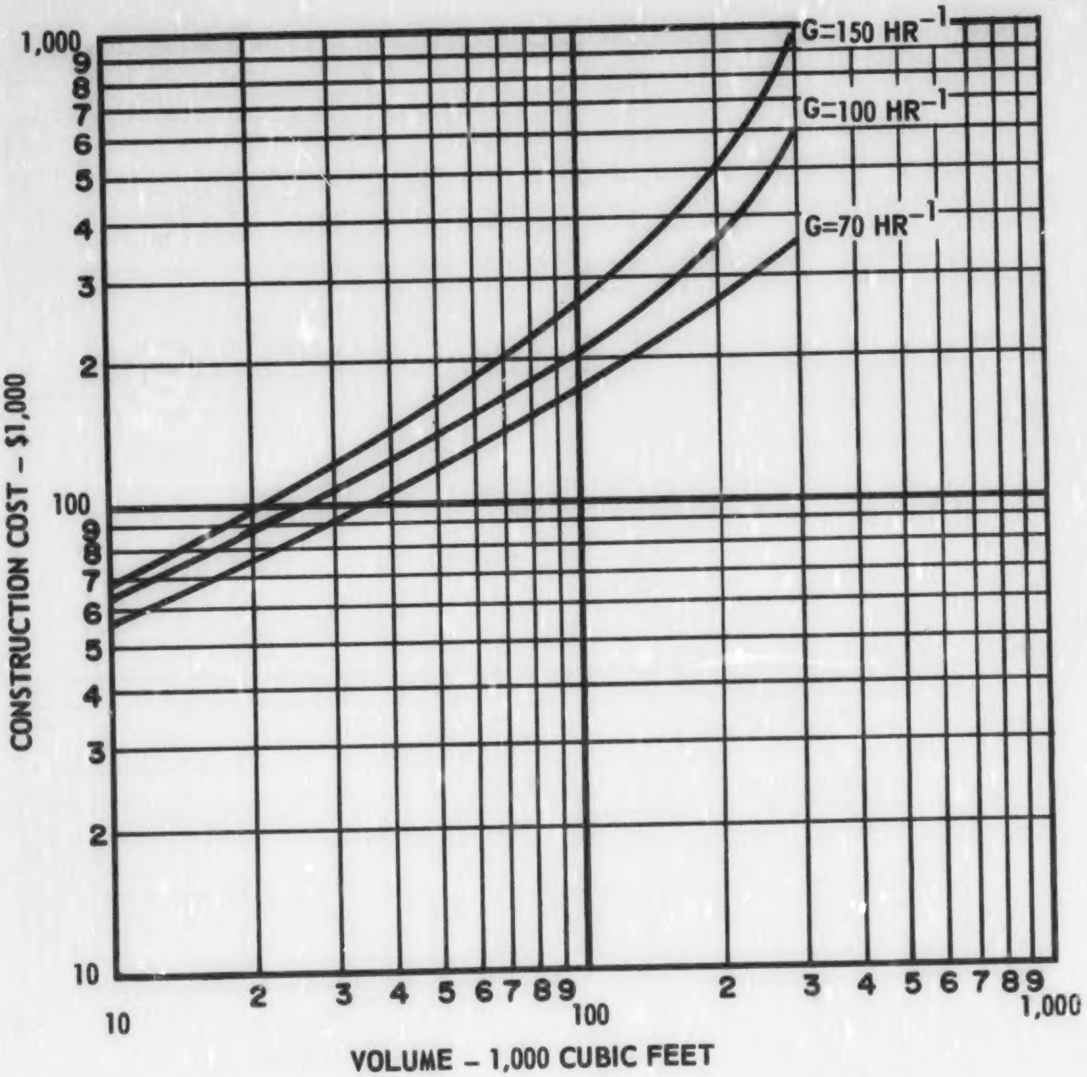


FIGURE 21 – FLOCCULATION BASIN – COST

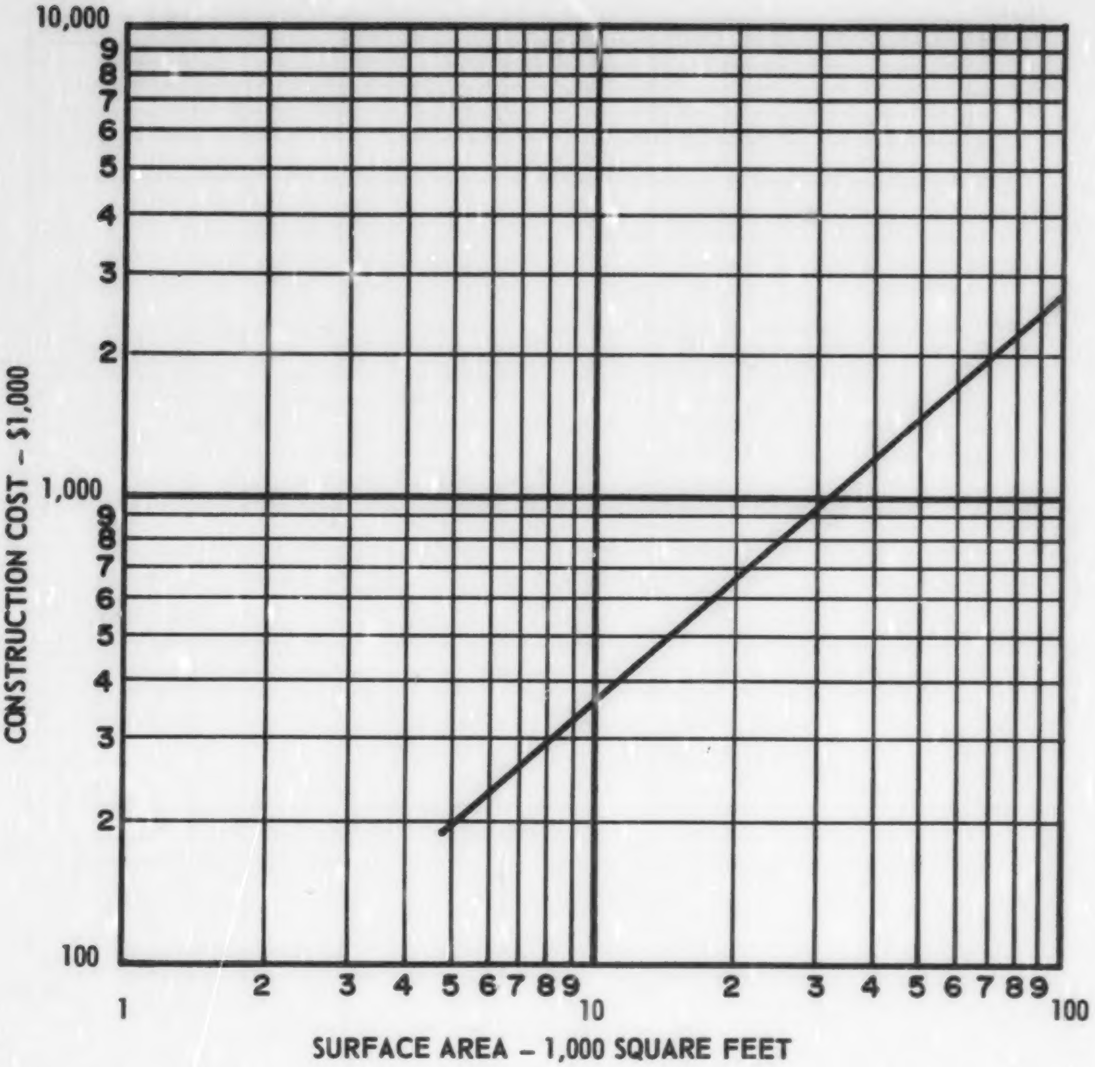


FIGURE 22 – SEDIMENTATION BASIN – COST

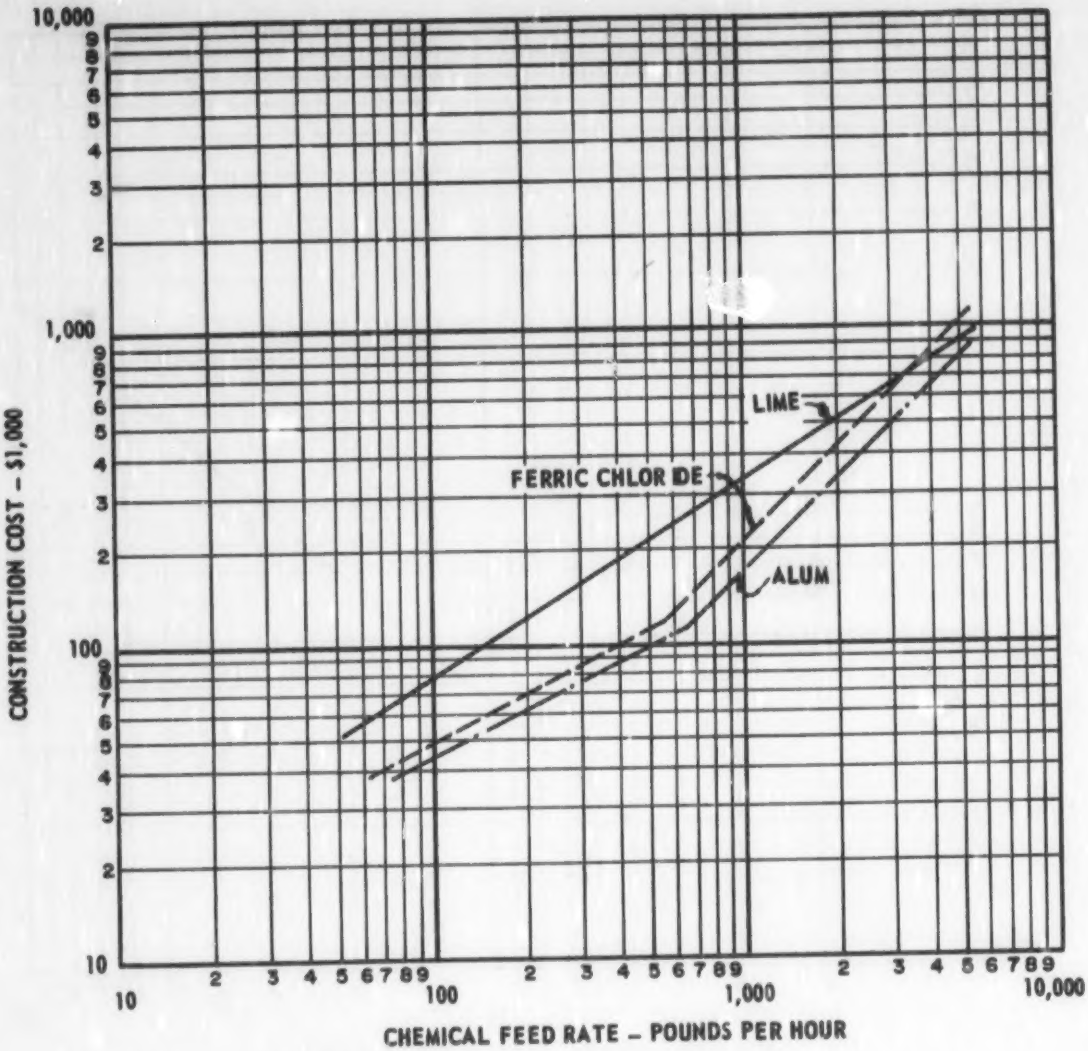


FIGURE 23—LIME, ALUM, FERRIC CHLORIDE FEED SYSTEMS-COST

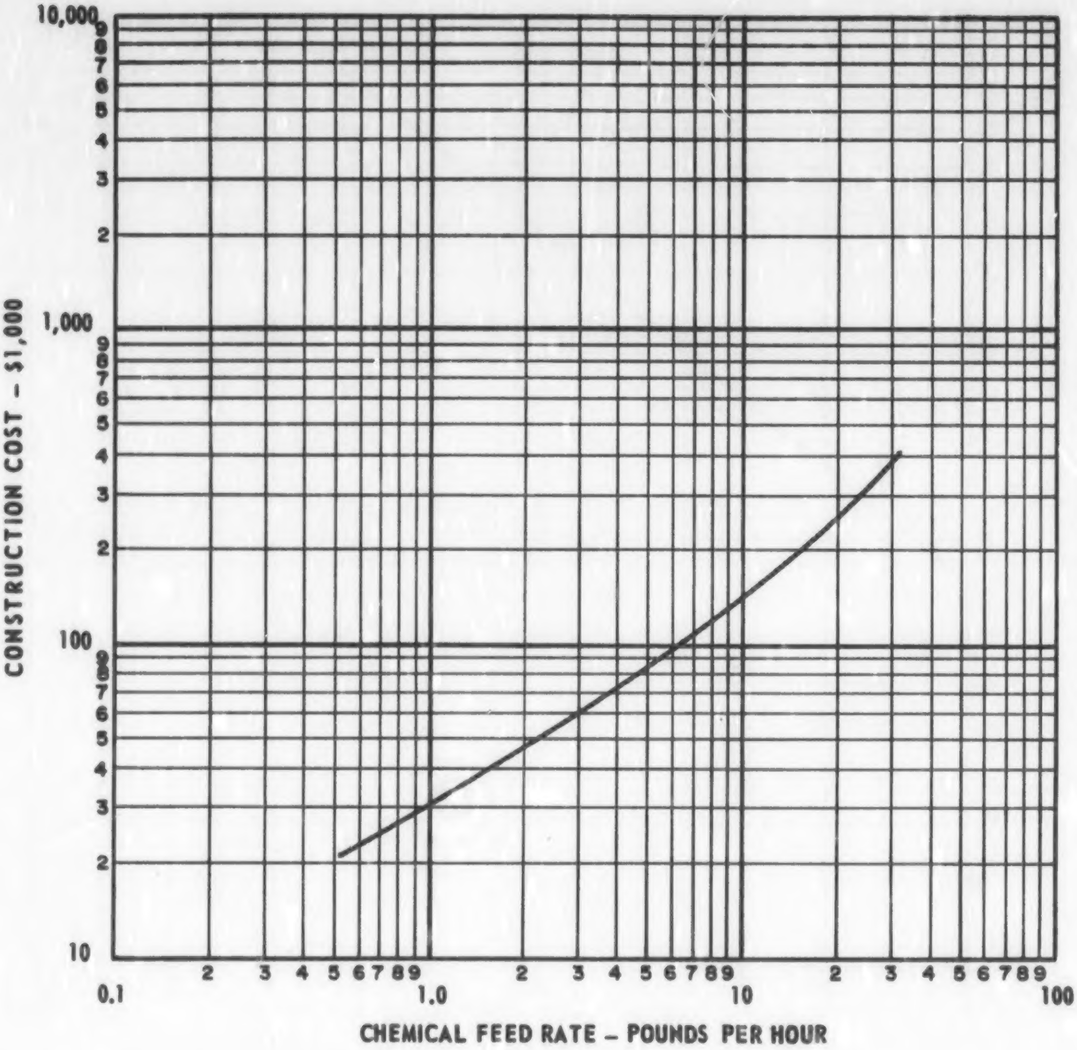


FIGURE 24 – POLYMER FEED SYSTEM – COSTS

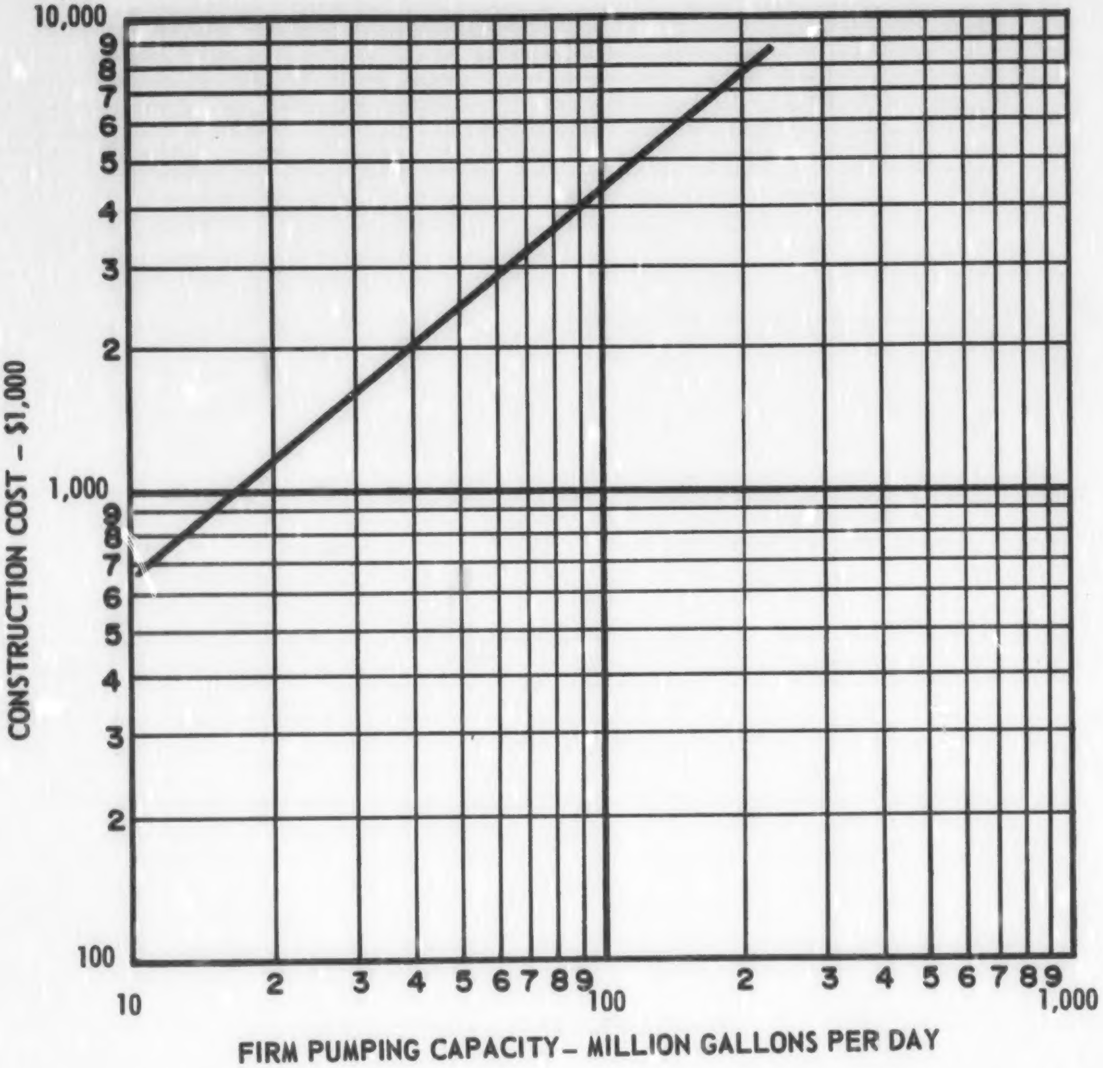


FIGURE 25 – RAW WASTEWATER PUMPING STATION – COST

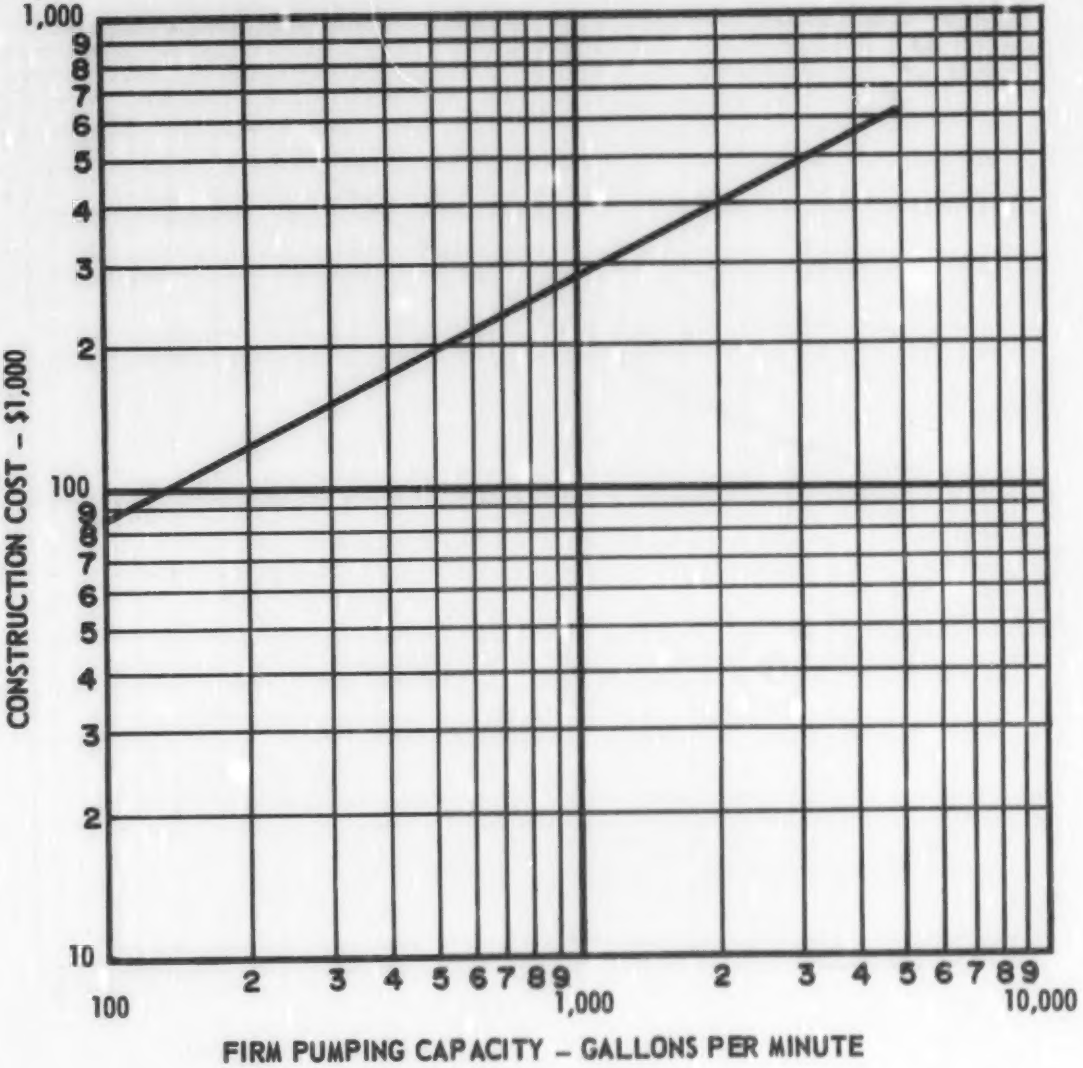


FIGURE 26 – SLUDGE PUMPING STATION – COST

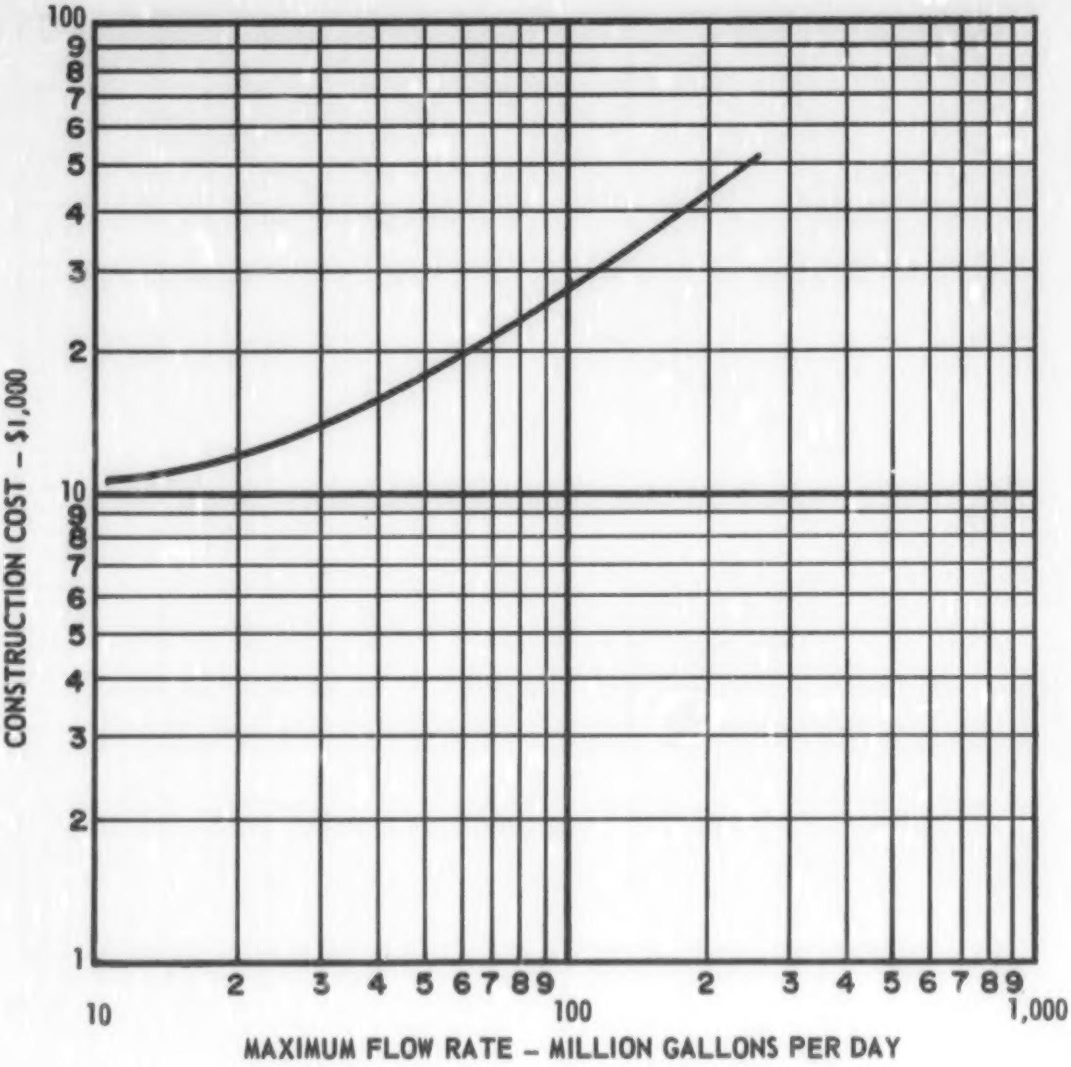


FIGURE 27 – FLOW MEASUREMENT – COST

SECTION IV

OPERATION & MAINTENANCE REQUIREMENTS

The requirements associated with operation and maintenance of facilities used to treat combined sewer overflows will be quite variable. At the present time, established data on these requirements are not available. A format is established which presents a basis for estimating operation and maintenance requirements, and can be modified for specific facilities or as additional information becomes available. Because very little actual data were available, data previously presented in the literature were heavily relied upon.

A. OPERATION & MAINTENANCE ITEMS

1. Operating & Maintenance Labor - Operating and maintenance of combined sewer overflow facilities does not require a full time staff, but generally is composed of individuals who are drawn from other departments, as required, to provide the necessary labor functions associated with the combined sewer overflow treatment plant. The general practice with intermittently operated plants is to schedule routine visits and equipment checks, by a roving maintenance man or operator, to perform maintenance on the facility on a routine basis, as established by the equipment requirements and to assign an operator when the plant becomes active. The operator generally is not required to activate the plant, but to monitor its operation to assure continuous operation in the event of malfunction of a device. However, plants using reliable equipment and which are totally automatic are not manned during operation unless equipment malfunction alarms a central location whereby an operator is dispatched. Following a storm event, it is typical to dispatch a crew to dewater and wash down the facility, and place it in readiness for the next storm event.

The operating and maintenance labor provided in this analysis includes constant allowance for routine visits and maintenance and for dispatching of an operator(s) when the plant is active and a cleanup crew to wash down the facility after the storm overflow ceases. Therefore, a constant amount of labor is provided whether the plant operates, or not; and a variable amount of labor is provided for the number of times and duration of the overflow event. Labor is presented in terms of manhours per year to accommodate varying wage scales.

2. Power - The energy required to operate a combined sewer overflow treatment facility is composed of the process equipment which is active only during the overflow period and heating and lighting of enclosed spaces. The cost associated with the power may basically be a demand charge since the power use is low compared to the maximum demand; however, many water utilities have rate schedules which incorporate the demand into other utility facilities locations which tends to average demand charges across the system. The rates for a specific location should be investigated prior to assigning a unit charge.

Power is presented in terms of Kwh per year for varying time of operation. The average power usage is assumed to be based on an average flow rate of forty-five percent of the rated capacity of the plant facility. Most storm overflows will not reach the plant capacity and a typical storm hydrograph indicates the plant will operate at peak flow only for a portion of time.

3. Chemicals - The chemical requirements are not presented in tabular or graphical form because the amount of chemicals used will basically be a function of the flow and dosage rate. Pacing control equipment based on flow is almost a necessity for proper operation of chemical feed equipment and feedback information such as pH or chlorine residual is advantageous for conservation of chemicals and attaining satisfactory results. The amount of chemical used should be based on the average flow treated; similar to that assumed for power usage.

4. Miscellaneous Supplies - Miscellaneous supplies include repair parts, truck time, tools, contracted maintenance work allowances, insurance, janitorial supplies, gas, oil, and other miscellaneous consumable products and other items not specifically accounted for elsewhere. The costs of this category are less than those which would be associated with a continuously operated plant, but essentially independent of the number of times or the duration of time the plant is operated.

Miscellaneous supply costs are presented as a dollar amount which is believed to best be inflated using the wholesale price index which reflects costs of a wide variety of goods and products.

5. Administrative Costs - Administrative costs will rightfully be charged against the overflow treatment facility. Generally speaking, the time of the wastewater and/or collection system superintendent, secretarial time and training effort which is attributable to the overflow treatment plant will be chargeable to the facility operation; however, most utility accounting systems do not provide for categorizing employee time against specific facilities and an arbitrary portion of administrative time is charged.

For the purposes of this study a portion of the administrative time which was reported in the previous study by Black & Veatch(1) is used to reflect administrative time. The portion is assumed to be a function of the capacity and frequency of use of the combined sewer overflow treatment facility.

Since combined sewer overflow treatment plants operate from 5 to 15 percent of the time as a general rule, it is assumed that the administrative charges against the combined sewer overflow treatment plant will be one half of the administrative requirements, during 10 percent of the year, or 5 percent of the overall administrative requirements. Therefore, 5 percent of the administrative labor presented in the Black & Veatch report(1) will be used in this presentation, (Figure 28). Likewise, the material and supply costs associated with administrative requirements are presented in Figure 29.

6. Laboratory And Sampling - Laboratory and sampling effort is primarily a function of the number of samples, and the types of analysis performed on each sample.

The numbers of samples and analyses presumed to be performed are outlined in this section. The unit time required for each analysis and sample are obtained from information derived from the laboratory director of Metropolitan Denver Sewer District No. 1 and from information presented in EPA's "Handbook for Analytical Quality Control in Water and Wastewater Laboratories". (27)

PARAMETER	UNIT TIME* (HOURS)
BOD	0.24
TSS	0.36
COD	0.36
TKN	0.36
NO3-NO2	0.18
NH3	0.18
PO4	0.18
Dissolved Oxygen	0.12
pH	0.07
Conductivity	0.07
Turbidity	0.10
Alkalinity	0.18
Color	0.12
Automatic Sample Obtained	0.24
Manual Sample Obtained	0.60

* Based on 10 percent nonproductive time plus 5 percent standardization and reagent preparation time plus 5 percent reporting time.

The laboratory and sampling requirements for various numbers of samples and assuming one sample per sampling point per day of operation are summarized below based on automatic samplers and the following analysis per sample:

BOD, TSS, COD, TKN, NO_3-NO_2, NH_3, PO_4, pH

LABORATORY MANHOURS REQUIRED PER YEAR

Number of Samples Collected Per Day	Number of Days of Operation Per Year				
	20	40	60	80	100
2	87	174	260	347	435
4	174	348	520	694	870
6	261	522	780	1,041	1,305
8	348	696	1,040	1,388	1,740
10	435	870	1,300	1,735	2,175

These data are presented in Figure 30.

A portion of the cost for laboratory supplies should be charged against the operation of the combined sewer overflow treatment facility. The material and supply costs presented in the Black & Veatch study(1) were about 0.70 to 3.00 dollars per manhour required in the laboratory per year. The larger plants required greater supply costs than the smaller plants. Because combined sewer overflow treatment plants are normally associated with the larger utilities, the supply costs will likely be in the range of 2.00 to 3.00 dollars per manhour.

The cost of laboratory materials and supplies are shown on Figure 31.

7. Yard Maintenance - If the land upon which the facilities are located are landscaped and grassed, the labor and supplies associated with maintenance and care of the yard may be a significant budget item. The requirements for the care of the yard work is dependent upon climate, types of plantings and area of site. Therefore, the requirements for yard maintenance are basically independent of the flow capacity of the plant. Guidelines are presented in the Dodge Guide(7) which relate yard maintenance to area and these are repeated here to arrive at a basis for estimating yard maintenance.

	Average Frequency/ Year	Labor (Hours/Year 1000 sq. ft.)	Materials (Dollars/Year 1000 sq. ft.)	Equipment* (Dollars)
Mowing	30	0.5	0.50	160
Fertilization	2	0.1	3.0	5
Crabgrass Control	1/3	0.05	1.50	-
Travel Time	30	**		
		0.65**	5	165

Area of Plantsite	Maintenance/ Labor (Hours)	Travel Labor (Hours)	Total Labor (Hours)	Material & Equipment Costs (Dollars)
50,000 sq. ft.	32.5	30	62.5	415
100,000 sq. ft.	65.0	30	95.0	665
150,000 sq. ft.	97.5	30	127.5	915
250,000 sq. ft.	162.5	30	202.5	1,415
500,000 sq. ft.	325.0	30	355.0	2,665
1,000,000 sq. ft.	650.0	30	680.0	5,165

These requirements are presented on Figures 32 and 33.

* Amortized over 5 years at 8 percent and independent of area.

** Travel time independent of area and should be added after calculating the area function requirements.

B. SWIRL OVERFLOW REGULATOR/CONCENTRATOR

1. Labor - In a previous study(28) the operation and maintenance requirements for swirl overflow regulators/concentrators were assumed to be constant for all sizes of units.

Cleaning of the unit may be done with automatic washdown facilities; however, the success of this method, especially on larger units should be investigated. Many utilities perform routine visits to unattended stations to assure the facility is operable when needed and for a check to assure the facility has not been vandalized. It is assumed that the unit will be visited every other week (26 times per year) and the inspection visit will require two hours, including travel time.

In addition it is assumed that units will require the following manhours of cleanup time for placing in service following each overflow event.

Surface Area (Square Feet)	Cleanup Manhours (Manhours/Event)	Travel To and From (Manhours/Event)	Total (Manhours/Event)
113	10	2	12
254	12.4	2	14.4
452	13.9	2	15.9
707	17.4	3	20.4
1,018	19.9	3	22.9
1,385	22.4	3	25.4
1,810	24.9	3	27.9

As a comparison, the 75th and Nall Station at Johnson County, Kansas is reported to require 32 manhours to wash down 8,000 square feet of basins per overflow event. The greater wall length with rectangular basins and the sludge collection equipment at Johnson County would probably cause increased wash down time.

Therefore, the sum of the labor requirements for the swirl overflow regulator/concentrator, based on the above requirements is as follows:

STORMWATER EVENT MAINTENANCE

Surface Area (Square Feet)	Routine Visits (Manhours)	Storm Overflow Events/Per Year			
		5	10	20	30
113	24	60	120	240	360
254	24	72	144	288	432
452	24	80	160	320	480
707	24	102	204	408	612
1,018	24	115	230	460	690
1,385	24	127	254	508	762
1,810	24	140	280	560	840

The labor requirements are shown graphically on Figure 34.

2. Power - There is no mechanical equipment associated with the swirl overflow regulator/concentrator, and therefore, no direct process power requirements associated with the unit function. There is a hydraulic head loss through the unit which may require energy to raise the liquid to the same level as existed prior to the swirl overflow regulator/concentrator; however, this will be attributed to any pumping stations required for the facility.

3. Miscellaneous Supplies - No miscellaneous costs have been assigned to the swirl overflow regulator/concentrator.

C. SCREENING

1. Stationary Screen

a. Labor - The stationary screen, like the swirl overflow regulator/concentrator, will likely only require washdown of the facilties after each storm event and routine visit to the plant during the remainder of the year. The routine visits are established as 24 hours per year independent of plant size. In addition, it is assumed that an operator would be dispatched to the plant twice per day at two hours each to assure proper operation is occurring during an overflow condition. Furthermore, it is assumed that each event will average 3 days each.

The washdown labor for each storm event has not been reported on a stationary screen installation and the following assumptions were made:

- Set up and shut down time - 1 hour
- Washing time per screen - 1 hour
- Travel time per event per person - 1 hour

The operating and maintenance labor requirements for the stationary screen installation based on the above are as follows:

LABOR REQUIREMENTS - MANHOURS/YEAR

Plant Capacity Million Gallons/Day	Storm Overflow Events Per Year			
	5	10	20	30
12	119	194	364	534
32	144	264	504	744
64	184	344	664	884
128	284	544	1,064	1,584
256	484	944	1,764	2,144

These labor requirements are shown on Figure 35.

b. Miscellaneous Supplies - There is no previous estimate for miscellaneous supplies specific to the stationary screen. The screen life is estimated to be long (20 years) and conscientious washing should relieve any serious replacement costs. The distribution and collection systems should also offer long service without major costs for replacement parts and servicing. Therefore, most of the miscellaneous supply costs will be related to janitorial servicing (painting, cleansers) and minor repair work. At this time it is only possible to assign an arbitrary value to miscellaneous supply costs which is shown on Figure 36.

c. Power - Although hydraulic head losses are inherent in the system, no power costs are directly associated with the stationary screen.

2. Horizontal Shaft Rotary Screens - The total annual maintenance, operating, and supply costs of a horizontal shaft rotary screen facility have been estimated at one percent of the installed facility cost. This is an arbitrary allowance which may or may not be realized.

a. Labor - The labor required for operation and maintenance of the screening facility will be composed of the same duties as assigned to previously outlined unit processes; plus programed maintenance for the spray nozzles, screen fabric, mechanical equipment and instrumentation hardware. The programed operation and maintenance of the installation is as follows:

Routine Visits: 2 times per month, 2 hours each

Plant Cleanup : 1 hour set up/shut down time, per storm event
3 manhour washdown per screen per storm event
1 hour travel time per storm event

Operator : 4 manhours per day during storm duration at an average 3 days per storm event

Maintenance : 3 man crew, 1 day per year per screen to check instrumentation, replace drive belts, sealing bands, lubricants and clean clogged screens and nozzles.

The labor requirements associated with the above program are as follows:

HORIZONTAL SHAFT ROTARY SCREEN
ANNUAL MANHOUR REQUIREMENTS

Screen Surface Area - Square Feet	Storm Overflow Events Per Year			
	5	10	20	30
315	203	358	668	978
630	242	412	752	1,092
1,260	320	520	920	1,320
2,520	476	736	1,256	1,776
5,040	788	1,168	1,928	2,688

These manpower requirements are shown graphically on Figure 37.

b. Miscellaneous Supplies - As with previous unit processes, no data are available to assign a value to costs for miscellaneous supplies; therefore requiring an arbitrary value. Costs are based on an assumption of 2,000 dollars per year plus 0.50 dollars per square foot of screen per year. The resulting cost is shown on Figure 38.

c. Power - The power required to operate the screen includes the screen rotation drive, washwater supply pump, and instrument air compressor. The associated horsepower for each have been derived from manufacturer's catalog values and are as follows:

HORIZONTAL SHAFT ROTARY SCREEN
ANNUAL POWER REQUIREMENTS

Screen Surface Area (Square Feet)	Rotational Drive (Horsepower)	Washwater Supply Pump (Horsepower)	Instrumentation Air (Horsepower)	Electrical Consumption (Kwh/day)*
315	5	5	1	216
630	7.5	7.5	2	336
1,260	15	15	4	672
2,520	30	30	8	1,344
5,040	60	60	16	2,688

* Based on 90 percent motor efficiency

The energy required for varying days of operation of the facility per year is shown on Figure 39.

3. Vertical Shaft Rotary Screen - The major investigation on vertical shaft rotary screens, to date, was performed by CH2M/Hill at Portland, Oregon(16). A followup study by the City of Portland(17) furthered the available information on vertical shaft rotary screen operation. In those studies, operation and maintenance costs for a 25 million gallon per day screening facility was estimated to be 18,500 dollars per year based on the following:

Labor - 1 manhour per hour of operation	$ 5,600
Equipment Maintenance - 5 percent of equipment cost	3,000
Screen Replacement (500 hour life)	3,500
Power	3,000
Gas	1,200
Cleaning Agent (Sodium Hydroxide)	700
Vehicle Operation and Maintenance	1,500
	$18,500

No other data on operation and maintenance costs have been located. In order to place the operation and maintenance requirements within the same framework as previously presented unit processes, the above requirements will be used for reference.

a. Labor - The labor requirements required for operation and maintenance will be similar to the horizontal shaft rotary screen; however, the closed system will likely require minimal washdown time as compared to the open basin installation. The programmed operation and maintenance of the installation is as follows:

Routine Visits:	2 times per month, 2 hours each
Plant Cleanup :	Shutdown time by operator required to check screens, for problems. 1 hour per screen
Operator :	4 manhours per day during storm duration at an average of 3 days per storm event.
Maintenance :	3 man crew 2 hours per year, per screen to replace and/or clean screens, adjust part settings, replace gear box oil, clean spray nozzles, check instrumentation up to 500 hours per year usage. Beyond 500 hours per year, add 0.02 manhours per hour per screen.

The labor requirements associated with the above program are as follows:

VERTICAL SHAFT ROTARY SCREEN
ANNUAL MANHOUR REQUIREMENTS

Station Capacity Million Gallons/Day	Storm Overflow Events Per Year			
	5	10	20	30
12	188	328	608	906
36	276	456	816	1,230
72	408	648	1,128	1,714
144	672	1,032	1,752	2,683
216	936	1,416	2,376	3,653

The manpower requirements are shown graphically on Figure 40. As a comparison to the previous estimate by CH2M/Hill(16), the manpower requirements for a 25 million gallon per day facility established above is about 2 manhours per hour of operation.

b. Miscellaneous Supplies - The CH2M/Hill estimate of miscellaneous supply costs offers guidance for these costs. The 8 screens proposed for the 25 million gallon per day facility would require 3,500 dollars (1970 dollars) for screen replacement. Each screening unit requires about 1,500 dollars in replacement parts. Based on the Portland overflow frequency and quantity data, each screen will operate about 45 percent of the time that any overflow occurs. Therefore, for the following number of days of operation, the screen replacement costs will be as tabulated.

VERTICAL SHAFT ROTARY SCREEN
SCREEN REPLACEMENT COSTS

Plant Capacity Million Gallons/ Day	Number of Days Overflow Occurs Per Year			
	20	40	60	80
12	648	1,296	1,944	2,592
36	1,944	3,888	5,832	7,776
72	3,888	7,776	11,664	15,552
144	7,776	15,552	23,328	31,104
216	11,664	23,328	34,992	46,656

The cleaning agent and other costs are arbitrary and for the purposes of this study are assumed to be comparable to the horizontal shaft rotary screens. Miscellaneous supplies are shown on Figure 41.

c. Power - Each screen is driven by a 5 horsepower motor and requires about 10 gallons per minute at 80 pounds per square inch backspray pressure. The horsepower required for the backspray is about 0.75 per screen unit. Instrument compressor air requirements are small and 0.25 horsepower is assigned for this power requirement. The resulting power requirement is 6 horsepower per operating screen or 2.7 horsepower per screen per hour an overflow occurs. Power requirements are summarized on Figure 42.

D. AIR FLOTATION

The available costs for operation and maintenance of air flotation units used for treatment of combined sewer overflows are limited to that reported(18). Costs reported include those associated with drum screens and flocculation and therefore are not directly usable in this study.

a. Labor - The labor requirements for operation and maintenance of air flotation units include that time required for routine visits, plant washdown following each storm event, and maintenance of the drive units, recirculation pump and reaeration pump. The programmed operation and maintenance for air flotation is based on the following:

Routine Visits:	2 times per month, two hours each
Plant Cleanup :	1 hour set up/shut down time per storm event, 0.004 manhours per square foot washdown time, and one hour travel time per storm event.
Operation :	One operator dispatched 2 times per day, 2 hours each to check plant operation during overflow at an average of 3 days per storm event.

Maintenance: 0.9 manhours per year per square foot to repack pumps, change lubricants, painting, and perform maintenance of equipment.

The labor requirements for the above program are as follows:

AIR FLOTATION
ANNUAL MANHOURS REQUIREMENTS

Surface Area (Square Feet)	Storm Overflow Events Per Year			
	5	10	20	30
400	106	184	340	496
800	114	204	376	584
1,600	152	264	488	712
3,200	200	344	632	920
6,400	306	524	960	1,396
12,800	508	864	1,576	2,288
25,600	922	1,564	2,848	4,132
51,200	1,750	2,964	5,392	7,820
100,000	3,234	5,444	9,864	14,284

Labor requirements for air flotation are shown on Figure 43.

b. Miscellaneous Supplies - The previous estimate for maintenance parts associated with drum screens and air flotation equipment for a 90 million gallon per day installation was 3,600 dollars per year. Other supplies and miscellaneous costs were not presented. An arbitrary miscellaneous supply cost has been assigned and is shown on Figure 44.

c. Power - The power to operate an air flotation unit varies with the manufacturer. The two major manufacturers of air flotation equipment use a different recycle ratio and thereby require different power utilization. For the purposes of this study, the higher of the two is presented. The power required is approximately 0.10 Kw/square foot for units having larger than 2000 square feet of surface area.

The power requirements are shown on Figure 45.

E. CHLORINATION

The costs associated with operation and maintenance of chlorine feed equipment were investigated in the Black & Veatch report(1) on costs of conventional treatment systems.

In this report several chlorination systems were investigated, including gaseous chlorine, chlorine dioxide and hypochlorite. The equipment for feeding gaseous chlorine and chlorine dioxide is similar and it may be anticipated, with some confidence, that the operation and maintenance requirements will be similar for each system. The hypochlorite feed using on-site generation equipment is believed to require the same level of labor effort and miscellaneous supply costs with added costs for electrode replacement. Because the plant will operate intermittently, this added cost will not be as much of a factor as for a continuously operated plant. At the present time there are few data on the life of the electrode and an assumption is made that a 10 year life will result in a cost of 50 dollars per year per ton of chlorine used.

Power costs for chlorine feeders are nominal and are not presented. Power costs for chlorine generation are considerable, but vary extensively between equipment manufacturers. For the purposes of this presentation power requirements for chlorine generation are 2.5 Kwh per pound of chlorine. Data for labor requirements and miscellaneous supply costs, other than those outlined above, are derived from the work done by Black & Veatch(1), assuming a proportional requirement based on the amount of time the unit is active.

Labor requirements are shown on Figure 46, miscellaneous supply costs are shown on Figure 47 and power requirements are shown on Figure 48.

F. HIGH INTENSITY CHLORINE CONTACT BASIN (RAPID MIX)

1. Labor - The labor required for rapid mix basins includes an allowance of 1 hour per day for routine maintenance when the plant is operating, 4 hours per unit every 6 months for oil change, and 1 to 16 manhours per overflow event for basin drainage and cleanup. The labor requirements are shown on Figure 49.

2. Miscellaneous Supplies - Miscellaneous supplies have been arbitrarily established and vary from 100 dollars per year for the 1,400 cubic feet basin to 1,000 dollars per year for the 37,000 cubic feet rapid mix basin. The miscellaneous supply requirements are shown on Figure 50.

3. Power Requirements - Power requirements are directly related to the velocity gradient and time of use. The power requirements are presented as a relationship of mixer horsepower and number of days of stormwater overflow on Figure 51.

G. FILTRATION

A detailed study of filtration of combined sewer overflows has been made previously(21). In that study operation and maintenance costs were synthesized, for a pumping station, drum screen, and granular media filters, based on 300 hours of operation per year. The requirements developed in that study were as follows:

Surface Area (square feet)	Labor (Mh/Yr)	Miscellaneous Supplies (Dollars)	Electrical (Kwh/Yr)
725	2,133	8,390	20,000
1,550	2,200	12,550	40,000
3,100	3,850	21,570	80,000
4,350	3,850	24,310	80,000
6,200	5,500	32,750	120,000

The above costs are not directly usable, except as reference to a combination of costs as presented in this study.

1. Labor - Labor costs for high rate filtration include routine visits, plant cleanup after each overflow event, and routine maintenance on the filters and support equipment. The programmed labor requirements are as follows:

Routine Visits : 2 per month/2 hours each.

Plant Cleanup : Wash filter walls, backwash each filter and place in readiness, check equipment; 1 hour per filter plus 1 hour set-up and shutdown time.

Operation : 4 hours per day during storm duration at an average of 3 days per overflow.

Plant Maintenance: 12 hours per year per filter.

The labor requirements based on the above program are as follows:

FILTRATION
ANNUAL MANPOWER REQUIREMENTS

Surface Area (square feet)	Storm Overflow Events Per Year			
	5	10	20	30
2,740	450	840	1,620	2,400
4,320	462	852	1,632	2,412
9,400	530	940	1,760	2,580
15,540	632	1,072	1,952	2,832

The labor requirements are shown on Figure 52.

2. Miscellaneous Supplies - The miscellaneous supplies required are assumed to be similar to those required for horizontal shaft rotary screens and are shown on Figure 53.

3. Power - The power requirements directly associated with filtration are those associated with backwash and surface wash pumping and those associated with instrumentation. Power to overcome headloss through the filter should be accounted for in facility pumping stations. Backwash and surface wash water has been assumed to require 5 percent of the average flow (45 percent of the flow capacity of the facility); the power requirements are about 6 Kwh per mg. Assuming 0.5 Kw per filter for instrumentation, the power requirements are as shown on Figure 54.

H. PEAK FLOW STORAGE

Peak flow storage facilities require minimal maintenance except washdown time after each storm event. The size of storage facilities is large compared to other stormwater facilities and the labor required for washdown will be exceptionally high if automatic washdown provisions are not provided. For example, a 200 million gallon reservoir, 18 feet deep will have an area of 34 acres. From the few data available, it appears that washdown time requires about 0.004 manhours per square foot, or 6,000 manhours per storm event for the 200 million gallon reservoir. With this large manpower requirement per event, it is doubtful whether cleaning would be performed after each storm unless automatic sprays which flushed the walls and floor were not provided. Alternatively the basin could be drained, ridding the reservoir of most of the deposited solids, the walls washed and the basin filled to a few feet to cover residual solids to minimize odor problems.

The approach used in this study to estimate operating and maintenance requirements is to provide automatic sprays which wash the walls; flush the floor with large volumes of water from the sewer or from storage, and an estimated amount of manual washing to finish the reservoir cleaning.

1. Labor - The labor requirements based on the above program are shown on Figure 55.

2. Miscellaneous Supplies - Miscellaneous supplies have been arbitrarily established as shown on Figure 56.

3. Power - The power required is limited to that required for the spray system. The spray water used in this analysis is 3 gallons per minute for 10 minutes per foot of reservoir wall. The spray water pressure is 60 pounds per square inch. The power requirements are shown on Figure 57.

I. FLOCCULATION

The basis for operation requirements for flocculation is similar to those presented for the rapid mix unit process except the cleaning labor is based on 0.004 manhours per square foot per event. Labor requirements are shown on Figure 58, miscellaneous supplies on Figure 59, and power requirements on Figure 60.

J. SEDIMENTATION

The basis for assessing operation and maintenance requirements for sedimentation basins is similar to that used for air flotation equipment since the equipment and structures are similar. The labor requirements are shown on Figure 61, and the materials and supplies on Figure 62. The power requirements are based on 0.1 horsepower per 1,000 square feet of basin and are shown on Figure 63.

K. CHEMICAL FEED, STORAGE, AND HANDLING

Operation and maintenance requirements for chemical feeding, storage, and handling consist of two major components - unloading of chemicals and operation and maintenance of chemical feeding equipment. Estimates of unit time requirements have been made based on data and observations at several plants, but primarily from the more detailed data obtained from the Metropolitan Denver Sewage Disposal District and the South Tahoe Public Utility District plants.

1. Lime - The labor required for lime feeding and storage is based on the following unit times:

Slaker : 1 hour/ 8 hour shift/slaker during use period

Feeder : 10 minutes/hour/feeder during use period

Slurry Pot: 30 minutes/day/feeder during use period

Unloading : 60 minutes/ton/bag unloading
10 minutes/ton pneumatic unloading

Miscellaneous supply costs were not available in a form isolated to chemical feeders and an arbitrary cost relationship of 3 percent of the equipment cost has been used.

Power requirements for lime feeding have been obtained from manufacturer's catalog information and are based on the following unit values:

	Kwh/1,000 lbs.
Slakers	0.8 - 1.6
Bin Activators	0.36 - 2.7
Grit Conveyors	0.06 - 0.45
Dust Collection Fans	0.02 - 0.04
Slurry Mixers	0.02 - 0.027
Slurry Feed Pumps	1.4 - 2.2

2. Alum and Ferric Chloride - The labor requirements associated with alum and ferric chloride feeding time have been based on the liquid form. The unit labor requirements are as follows:

Unloading : 90 minutes per 4,000 gallon truck

Metering Pump: 15 minutes/day/pump

Miscellaneous supplies were arbitrarily set at 3 percent of the equipment costs and power requirements are based on the use of metering pumps.

3. Polymer - The operation and maintenance requirements for polymer feeding are based on the unit labor requirements as follows:

Unloading : 1 hour/ton (50 lb. bags)

Maintenance : 1 manhour/day/feeder when in use

Mixing Labor : 30 hours/1,000 lb.

Miscellaneous Supplies: 3 percent of equipment cost

Power : Use of metering pumps plus 48 Kwh/1,000 pounds for mixing

Labor requirements for chemical feeding are shown on Figure 64. Miscellaneous supply costs are shown on Figure 65 and power requirements on Figure 66.

L. RAW WASTEWATER PUMPING

The previous work by Black & Veatch on operation and maintenance requirements for raw wastewater pumping stations serves as a basis for the data presented in this study. The labor requirements for operation and maintenance have been assumed to be proportional to the operating time, with a constant requirement of 8 manhours to wash the wet well after each storm event and 24 hours per year to check and test equipment and controls between overflow events.

Miscellaneous supply costs are assumed to be one-tenth of the cost as compared to a continuously operated station. Power costs are presented in relationship to days of operation assuming the average flow is 45 percent of the peak flow, the total pumping head is 35 feet and the wire to water efficiency of the driver is 65 percent. For other conditions, this requirement is easily convertible and should be done for specific installations.

Labor requirements are shown on Figure 67, miscellaneous supply costs on Figure 68, and power requirements on Figure 69.

M. SLUDGE PUMPING

The previous work by Black & Veatch (1) also serves as a basis for the data presented herein. Since sludge pumping stations are usually directly connected to the solids separation process which it serves, and does not have a separate wet well, the station alone will likely require operation and maintenance in direct proportion to its usage, and no cleanup after each overflow event is included.

Power requirements are presented on the basis of a pumping head of 25 feet with a weir to water efficiency of 50 percent. Labor requirements are shown on Figure 70, miscellaneous supply costs on Figure 71 and power requirements on Figure 72.

N. FLOW MEASUREMENT

No individual requirements for flow measurement are included in this report. The operation and maintenance requirements are minor compared to other unit processes presented and are assumed to be included in those requirements presented for raw wastewater pumping.

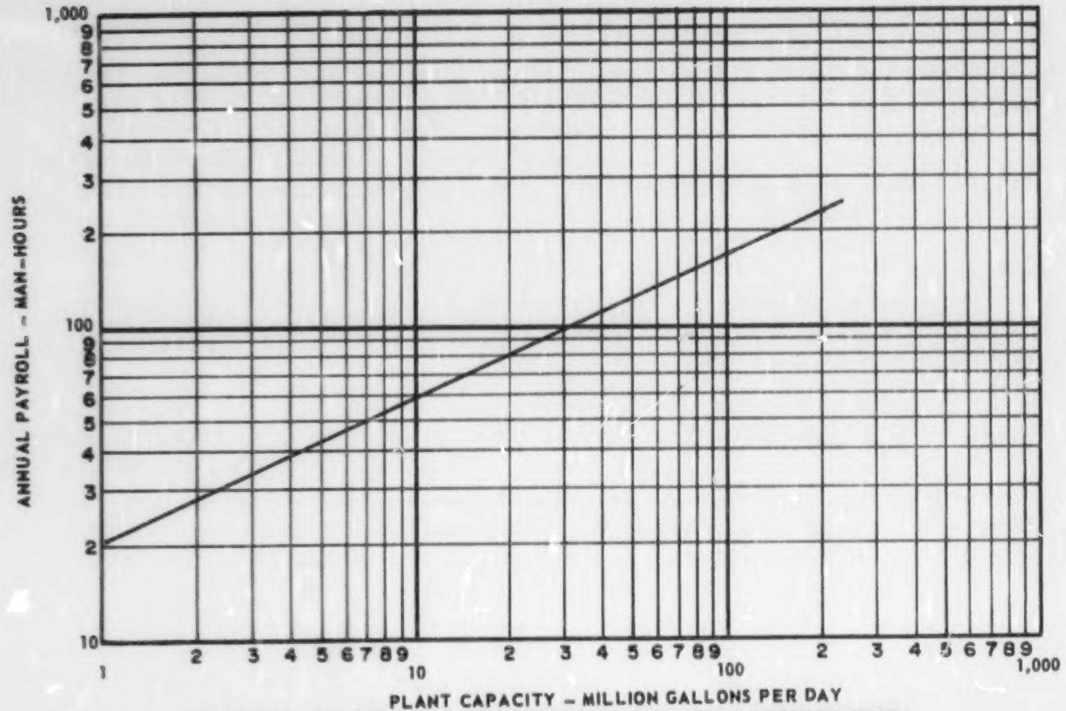


FIGURE 28 - ADMINISTRATION & GENERAL MAN-HOUR REQUIREMENTS

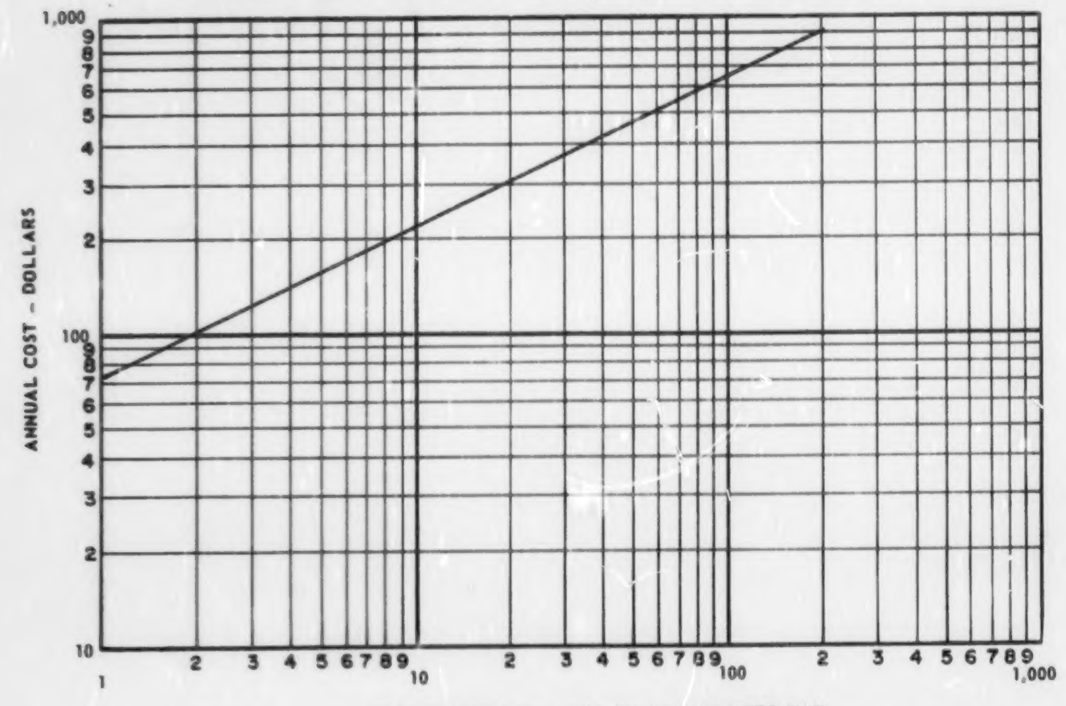


FIGURE 29 - ADMINISTRATION & GENERAL-MISCELLANEOUS SUPPLY COSTS

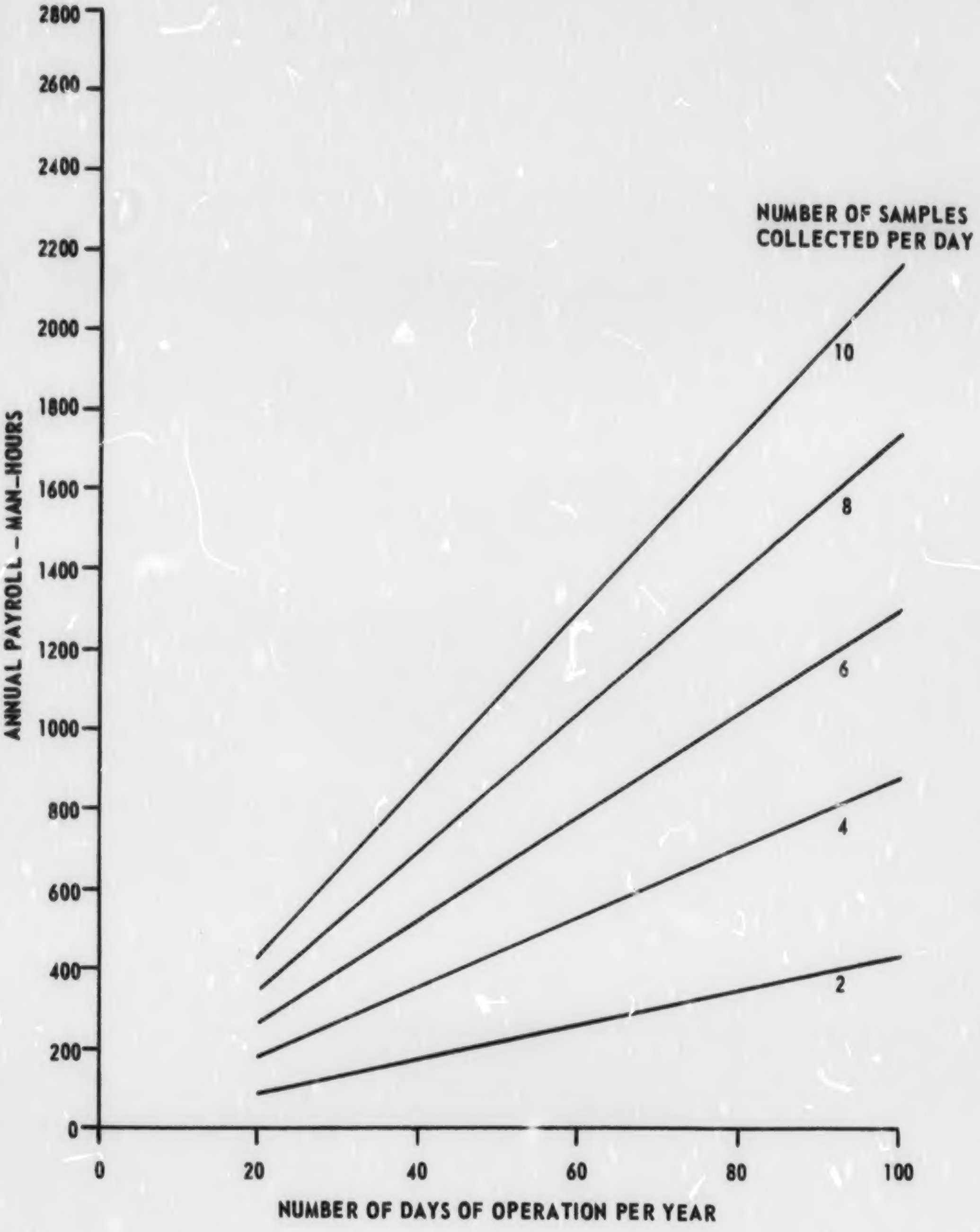


FIGURE 30 LABORATORY MAN–HOUR REQUIREMENTS

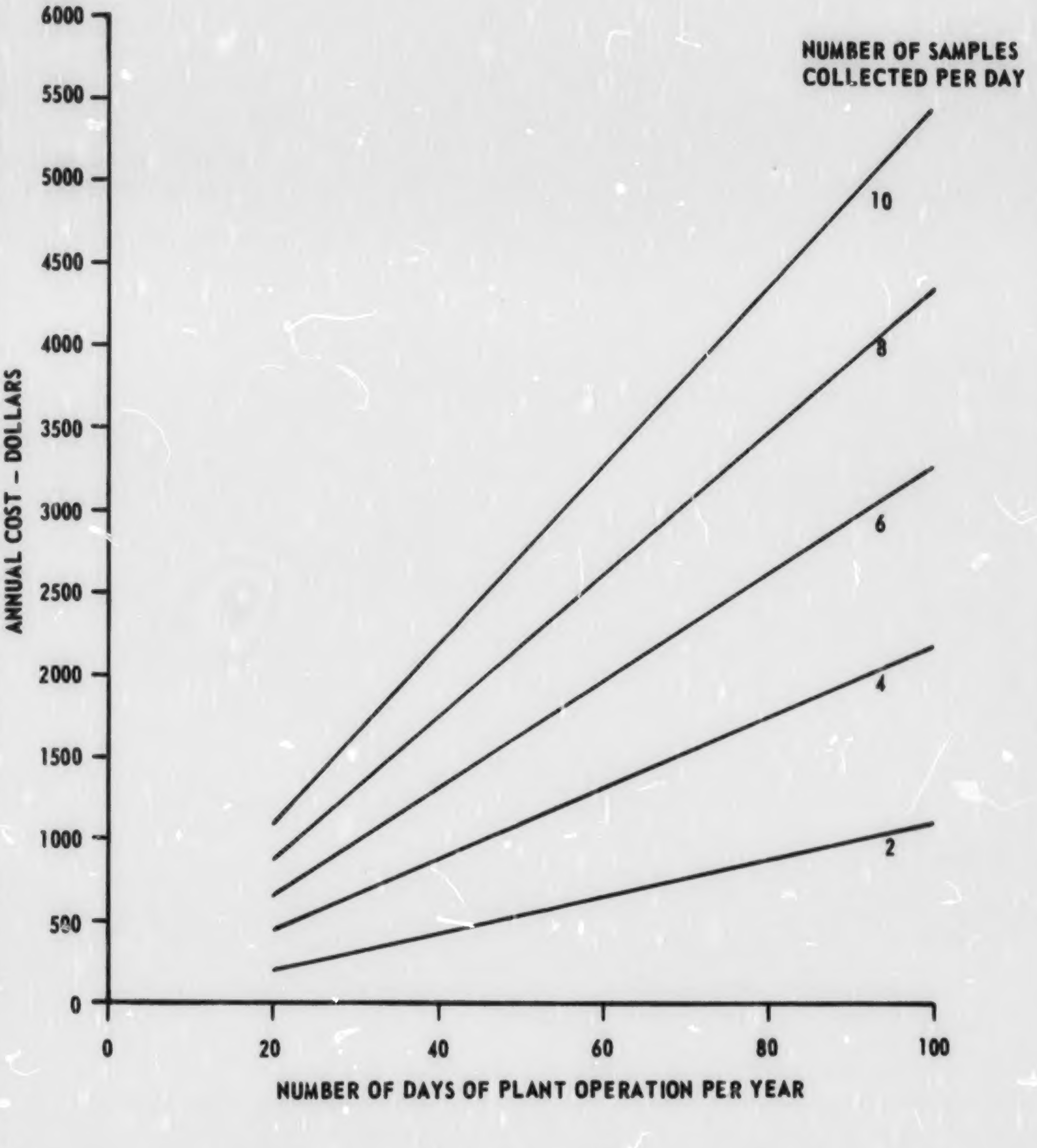


FIGURE 31 LABORATORY, MISCELLANEOUS SUPPLY COSTS

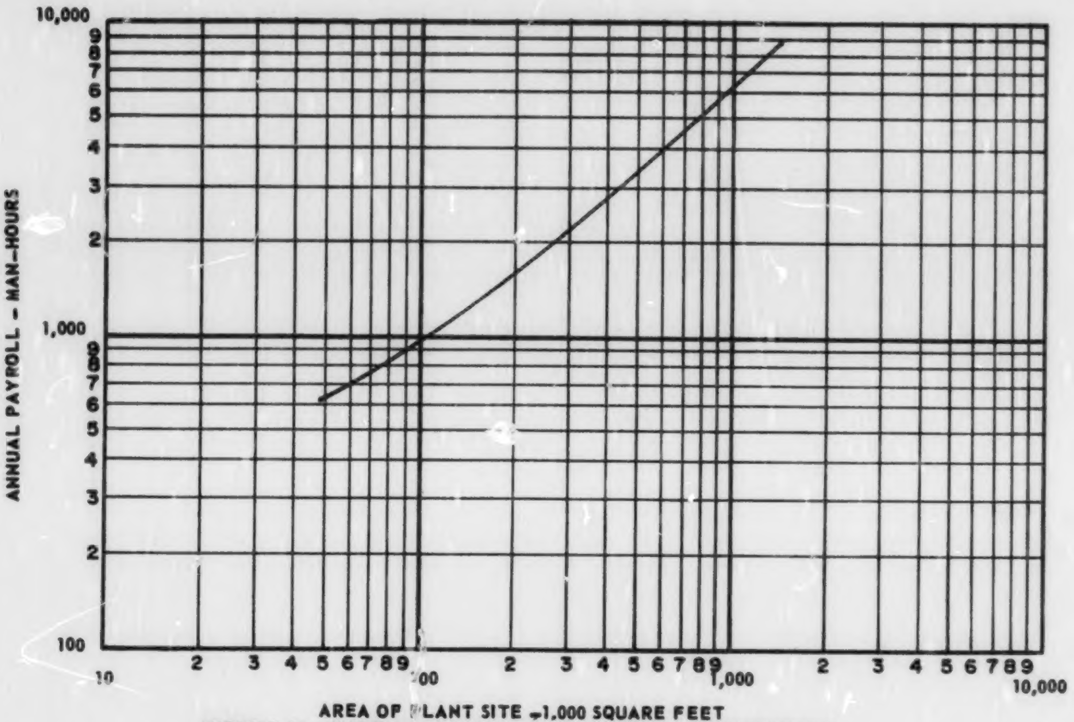


FIGURE 32 – YARD MAINTENANCE-MAN-HOUR REQUIREMENTS

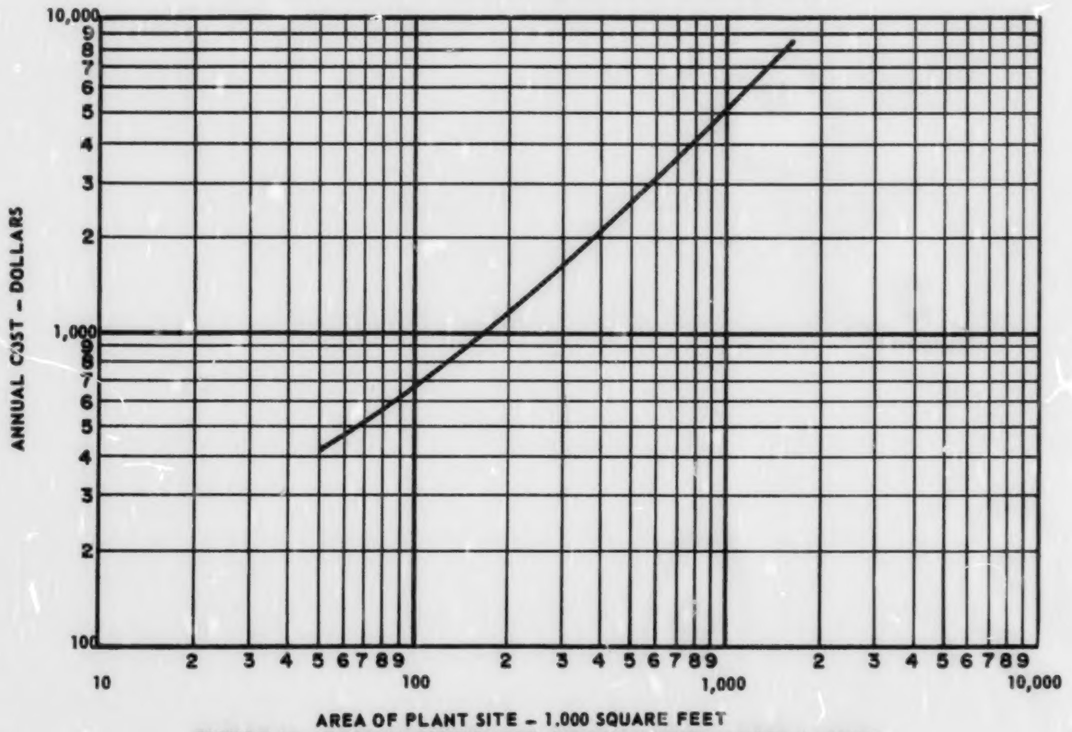


FIGURE 33 – YARD MAINTENANCE-MISCELLANEOUS SUPPLY COSTS

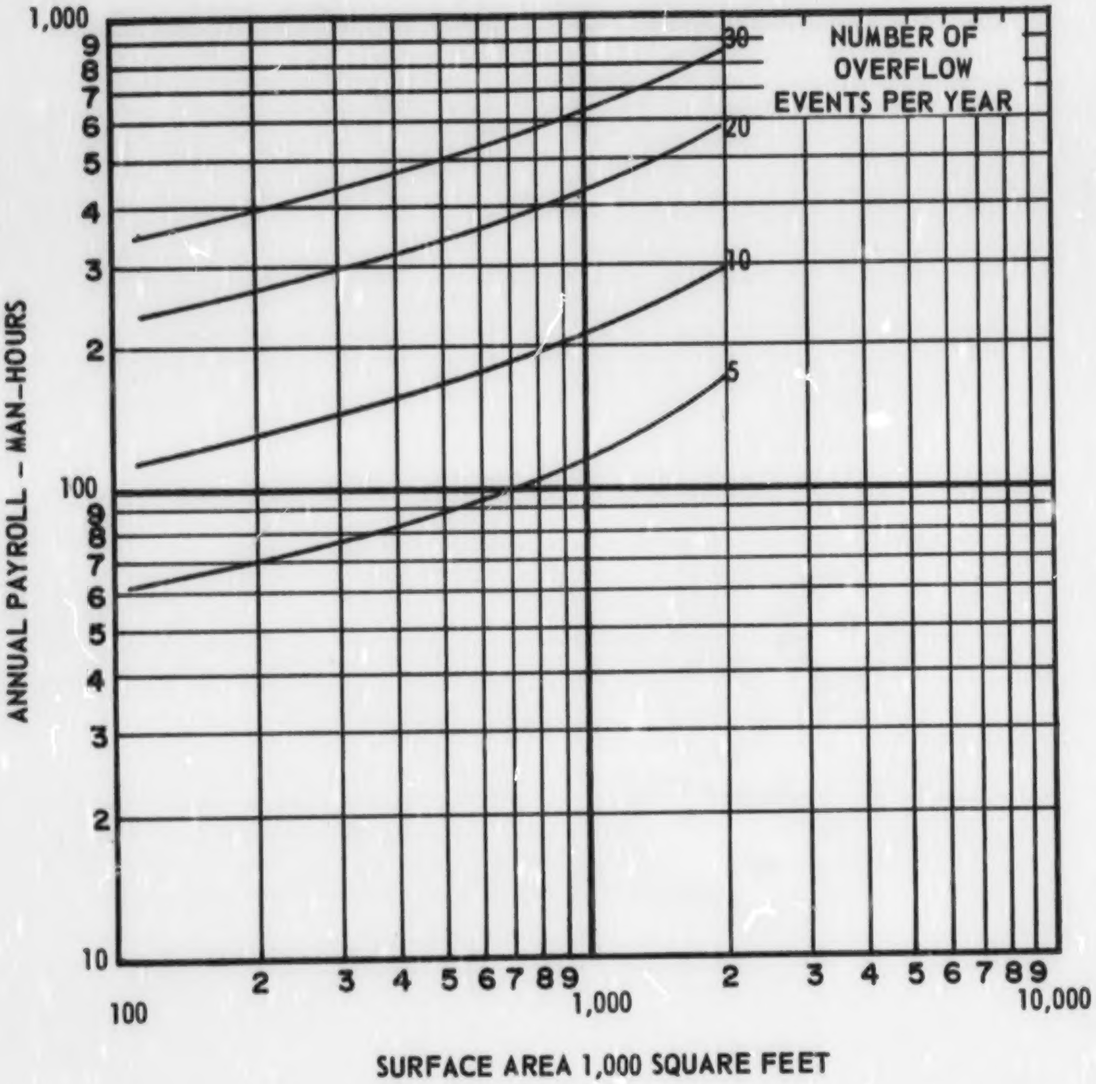


FIGURE 34 - SWIRL OVERFLOW REGULATOR/CONCENTRATOR MAN-HOUR REQUIREMENTS

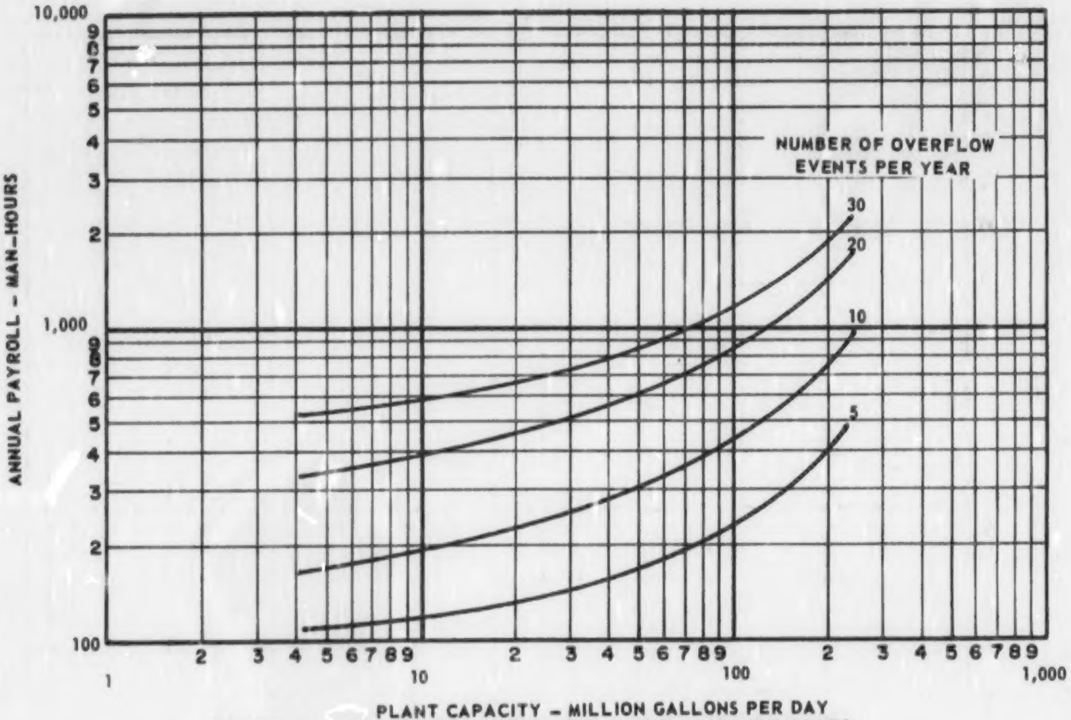


FIGURE 35- STATIONARY SCREEN-MAN-HOUR REQUIREMENTS

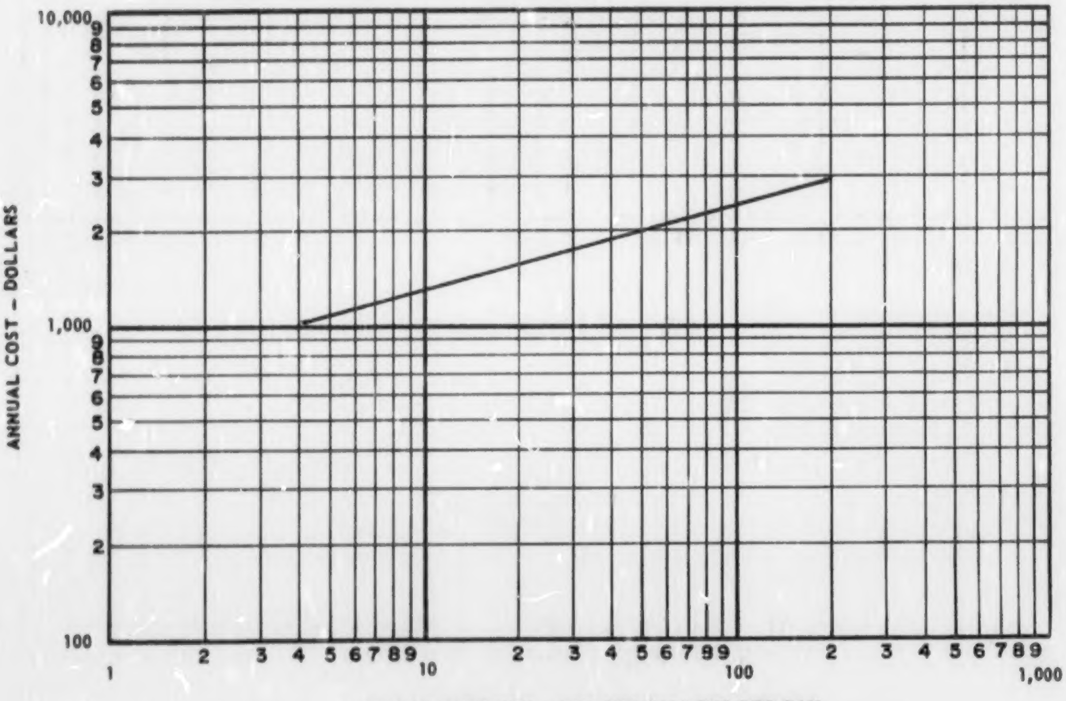


FIGURE 36-STATIONARY SCREEN-MISCELLANEOUS SUPPLY COSTS

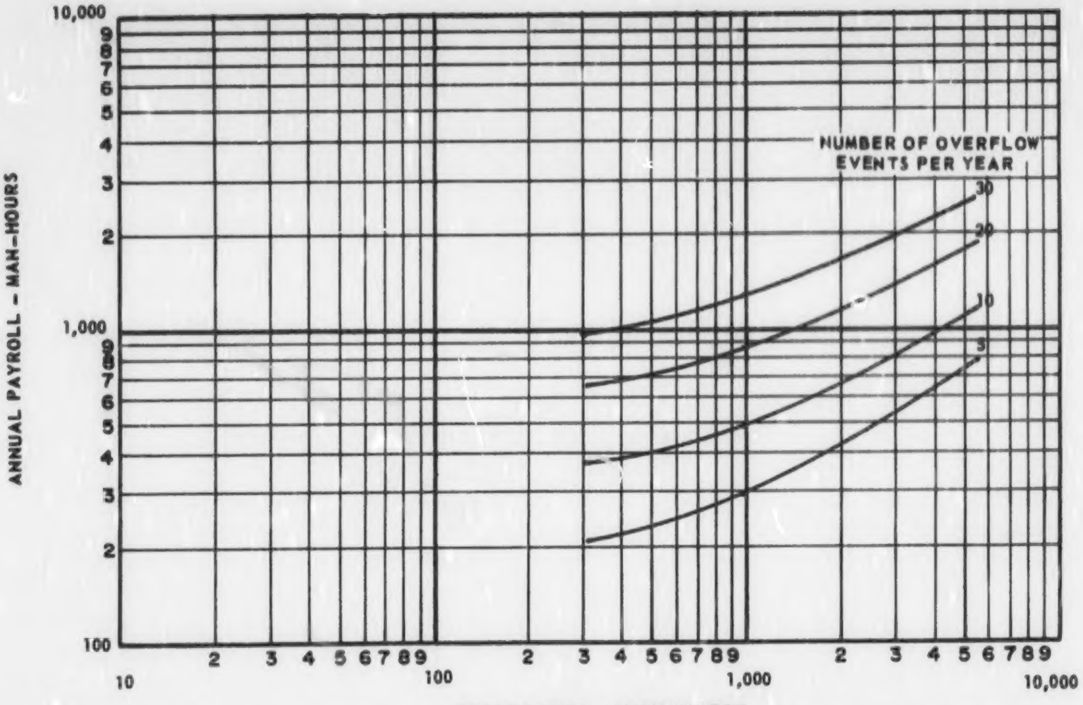


FIGURE 37—HORIZONTAL SHAFT ROTARY SCREENS-MAN-HOUR REQUIREMENTS

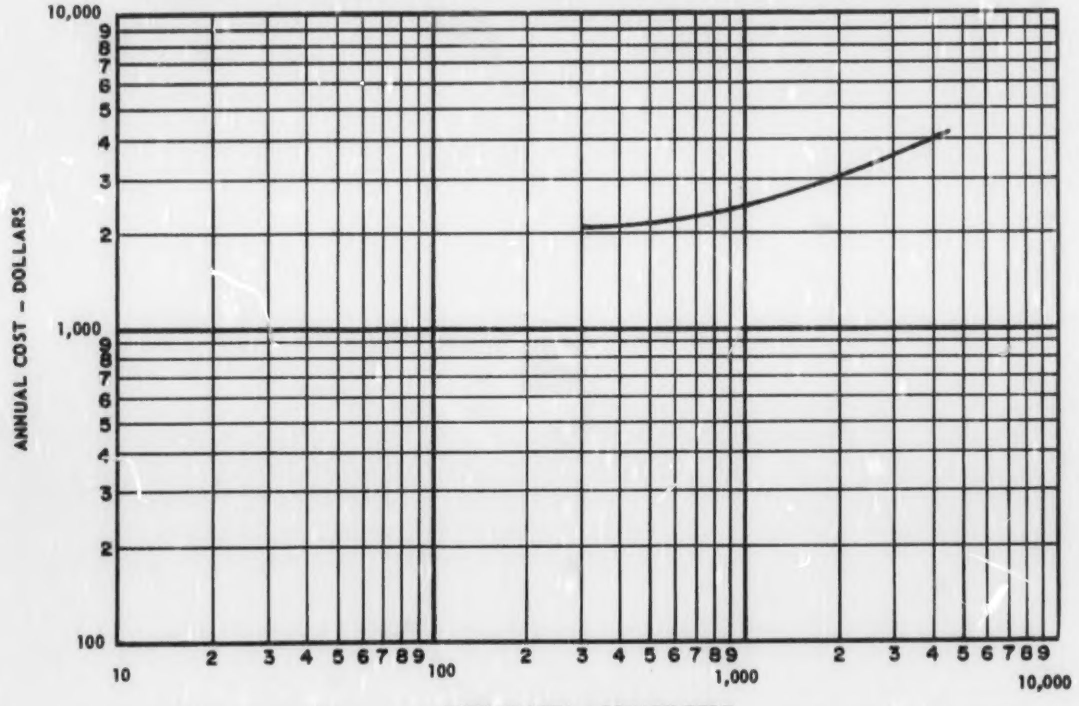


FIGURE 38—HORIZONTAL SHAFT ROTARY SCREENS-MISCELLANEOUS SUPPLY COSTS

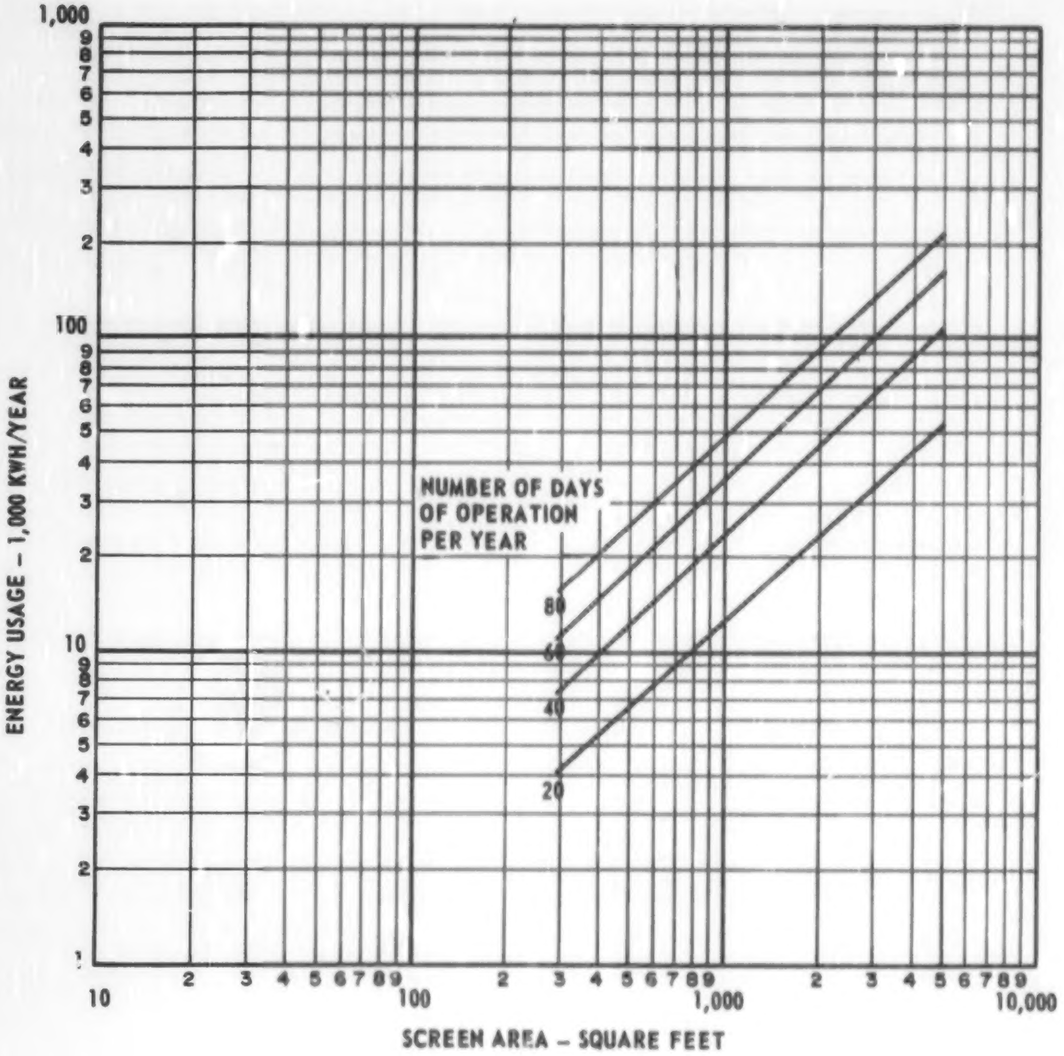


FIGURE 39 – HORIZONTAL SHAFT ROTARY SCREEN-POWER REQUIREMENTS

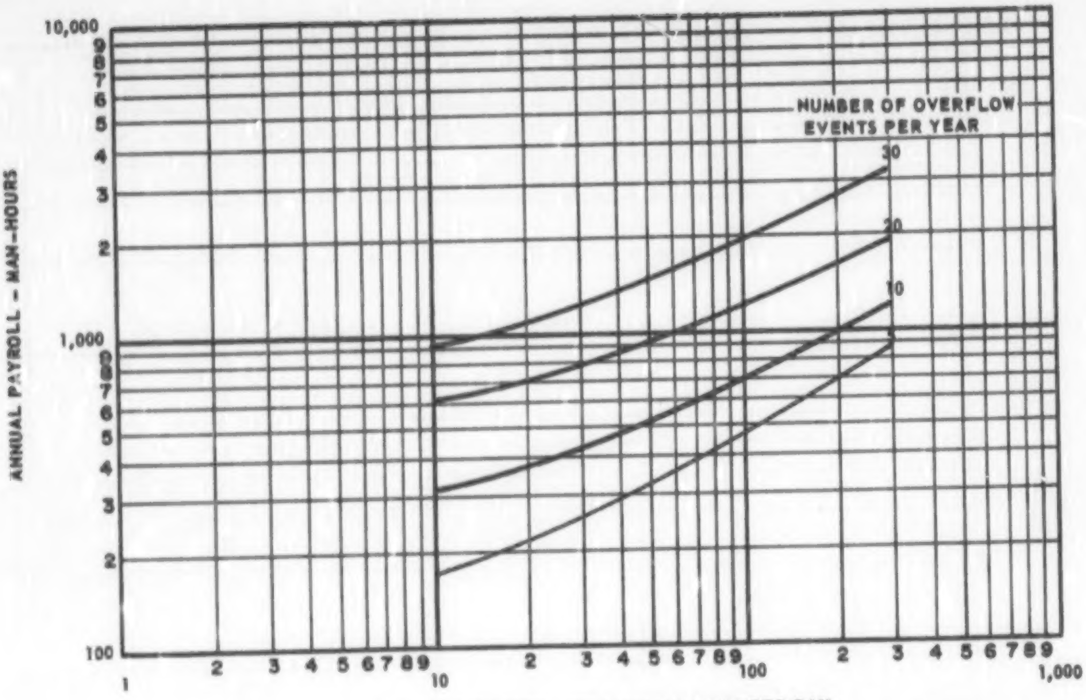


FIGURE 40 – VERTICAL SHAFT ROTARY SCREEN-MAN-HOUR REQUIREMENTS

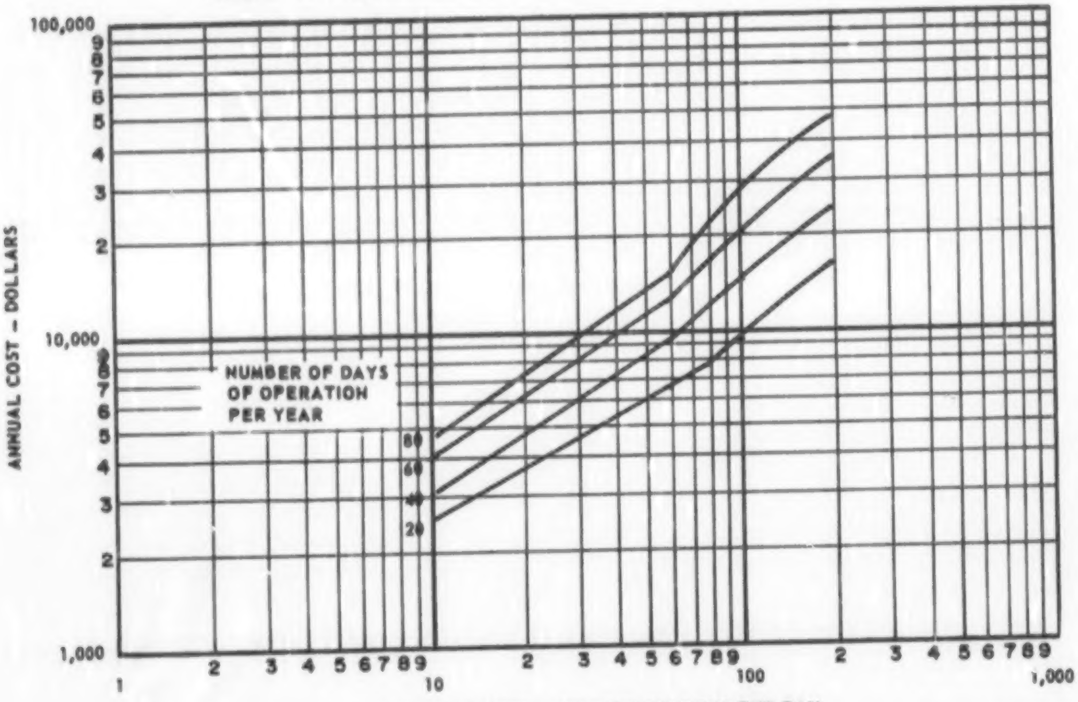


FIGURE 41– VERTICAL SHAFT ROTARY SCREEN-MISCELLANEOUS SUPPLY COSTS

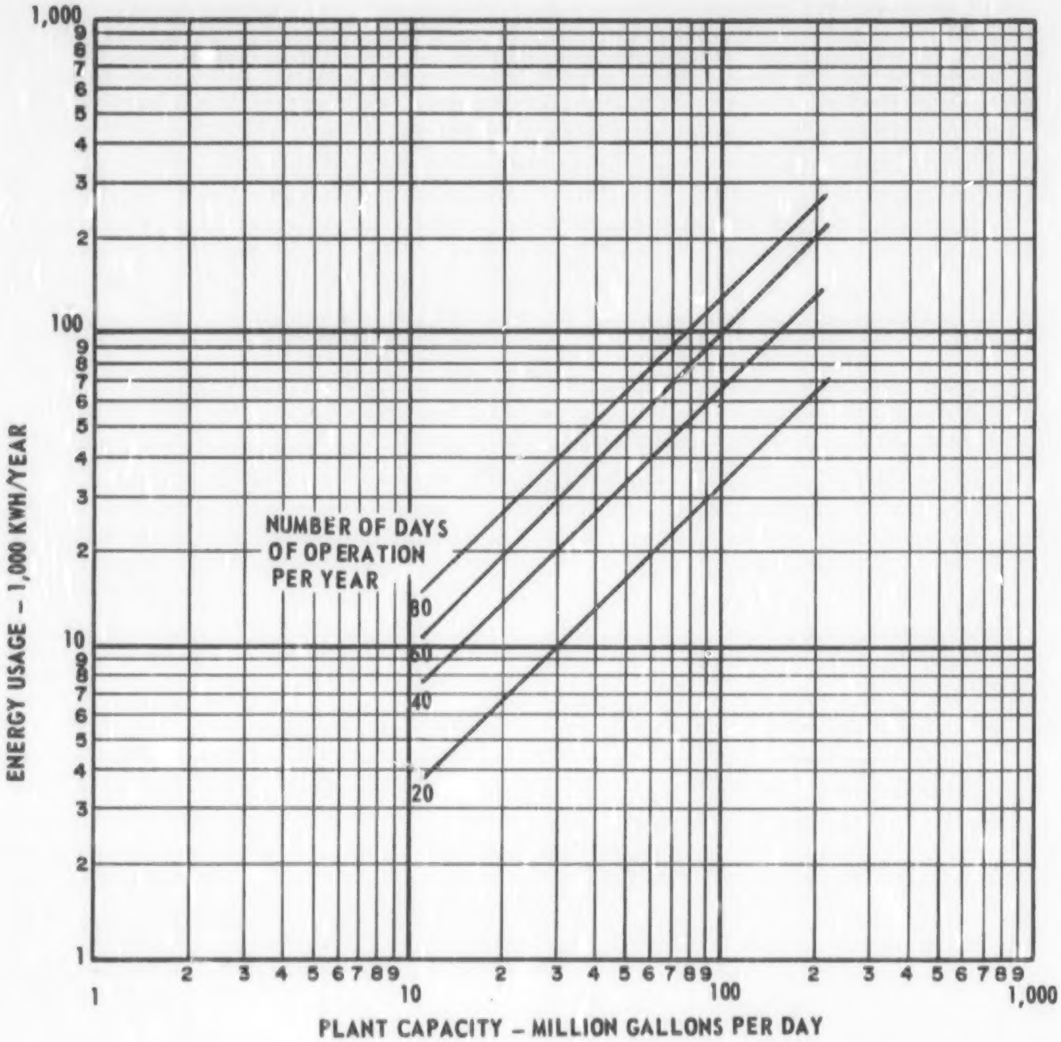


FIGURE 42 – VERTICAL SHAFT ROTARY SCREEN-POWER REQUIREMENTS

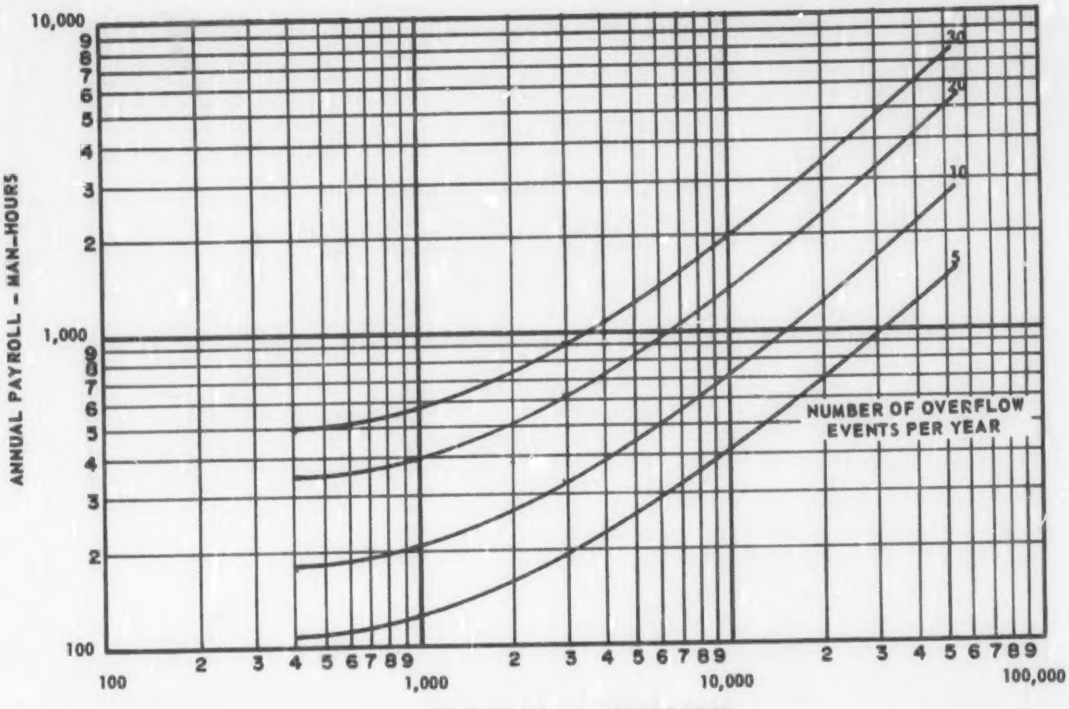


FIGURE 43—AIR FLOTATION-MAN-HOUR REQUIREMENTS

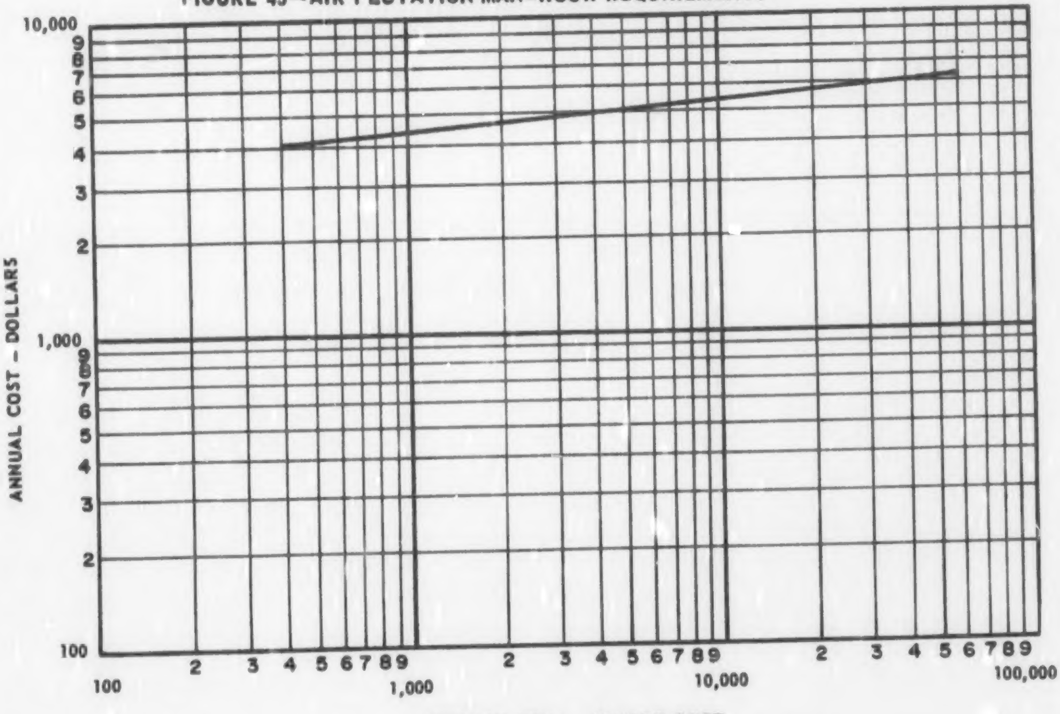


FIGURE 44—AIR FLOTATION-MISCELLANEOUS SUPPLY COSTS

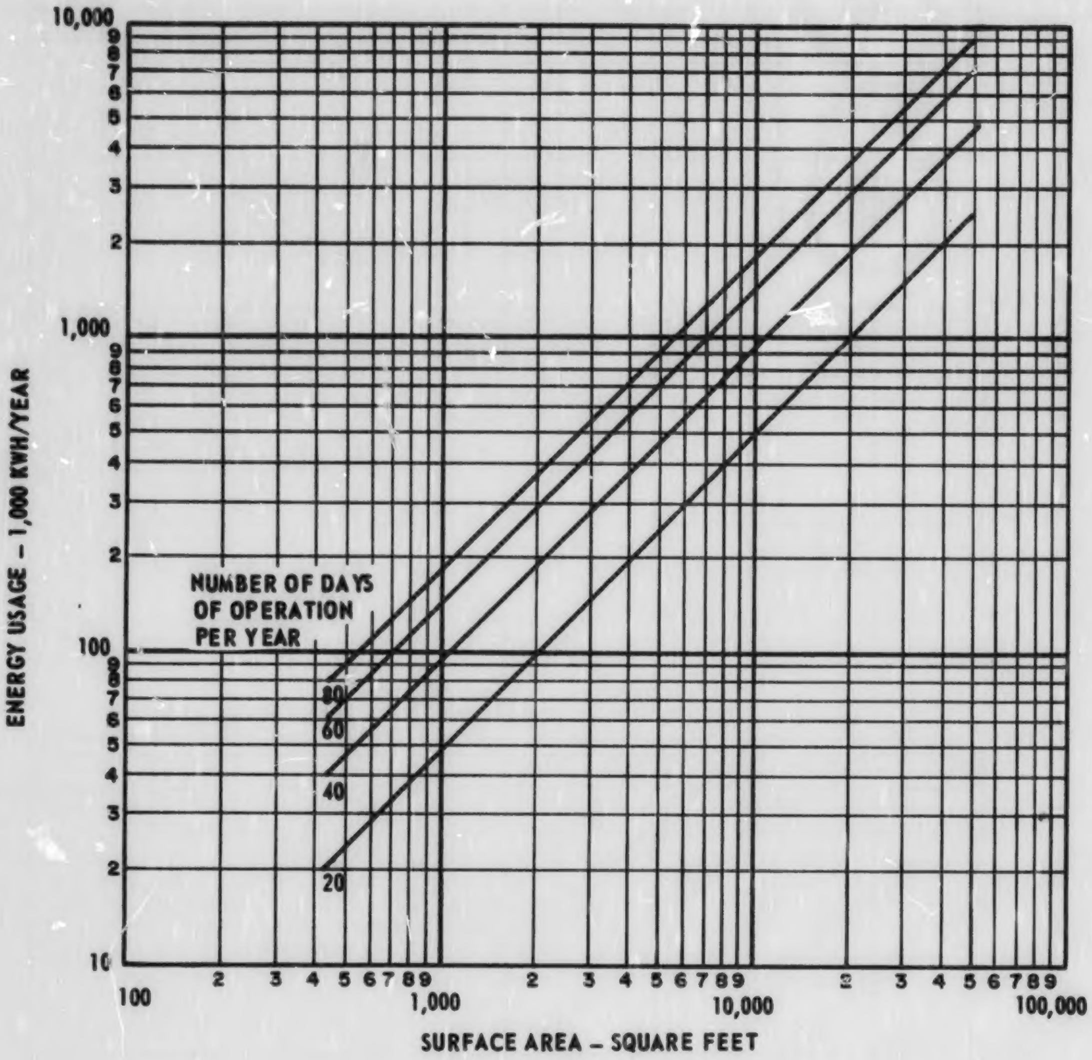


FIGURE 45 – AIR FLOTATION-POWER REQUIREMENTS

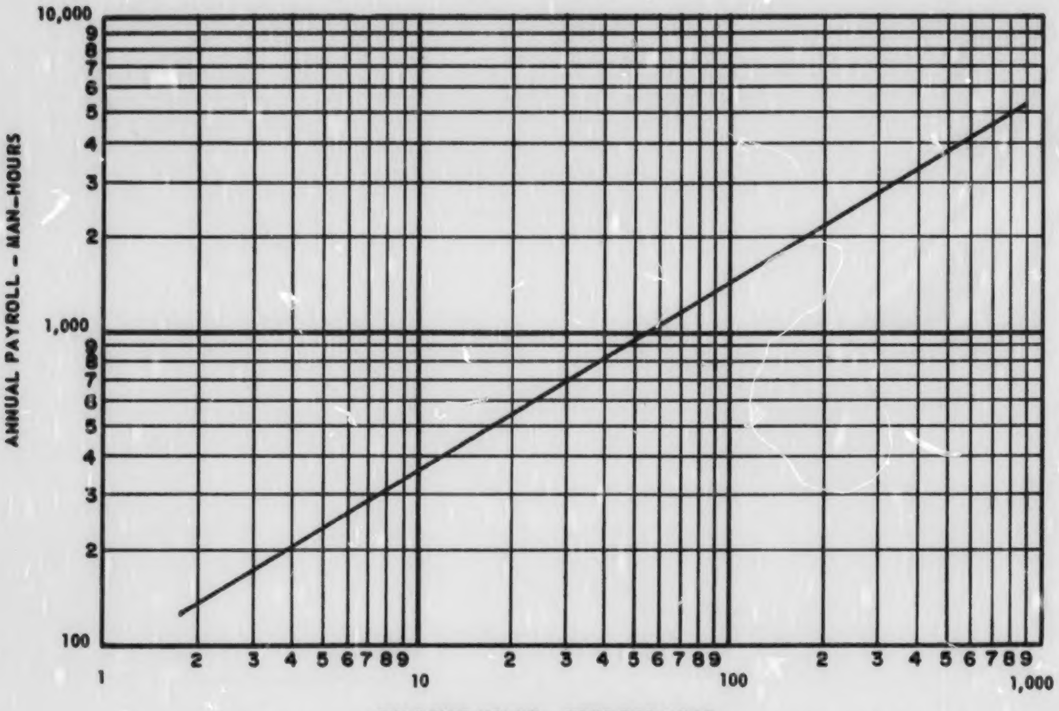


FIGURE 46 – CHLORINE FEED EQUIPMENT-MAN-HOUR REQUIREMENTS

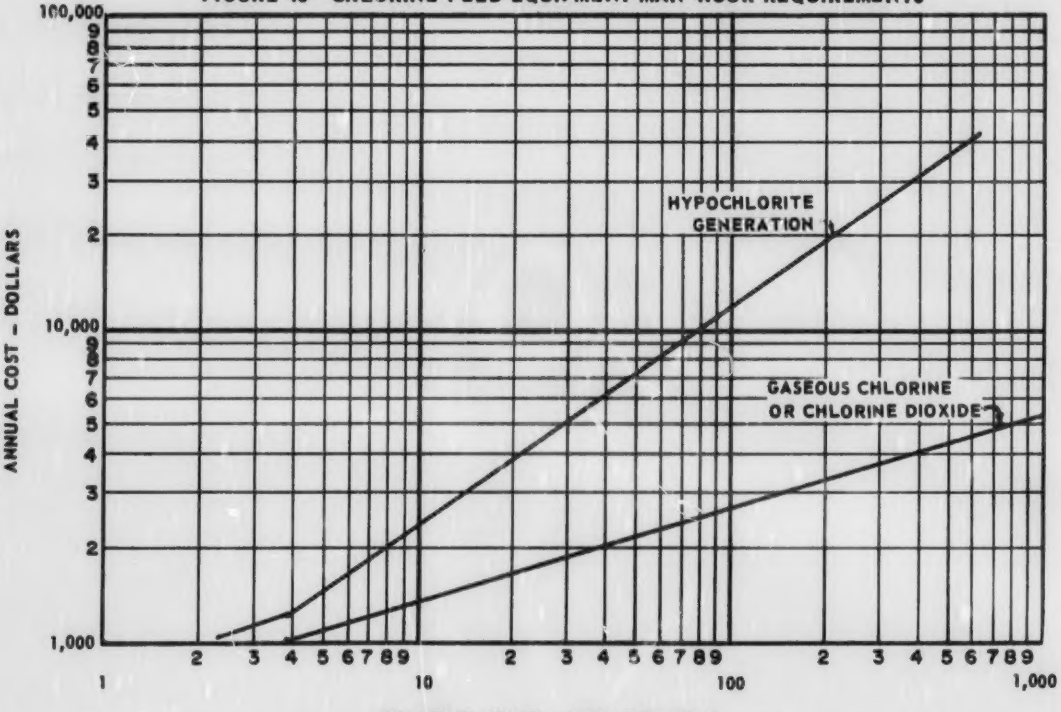


FIGURE 47 – CHLORINE FEED EQUIPMENT-MISCELLANEOUS SUPPLY COSTS

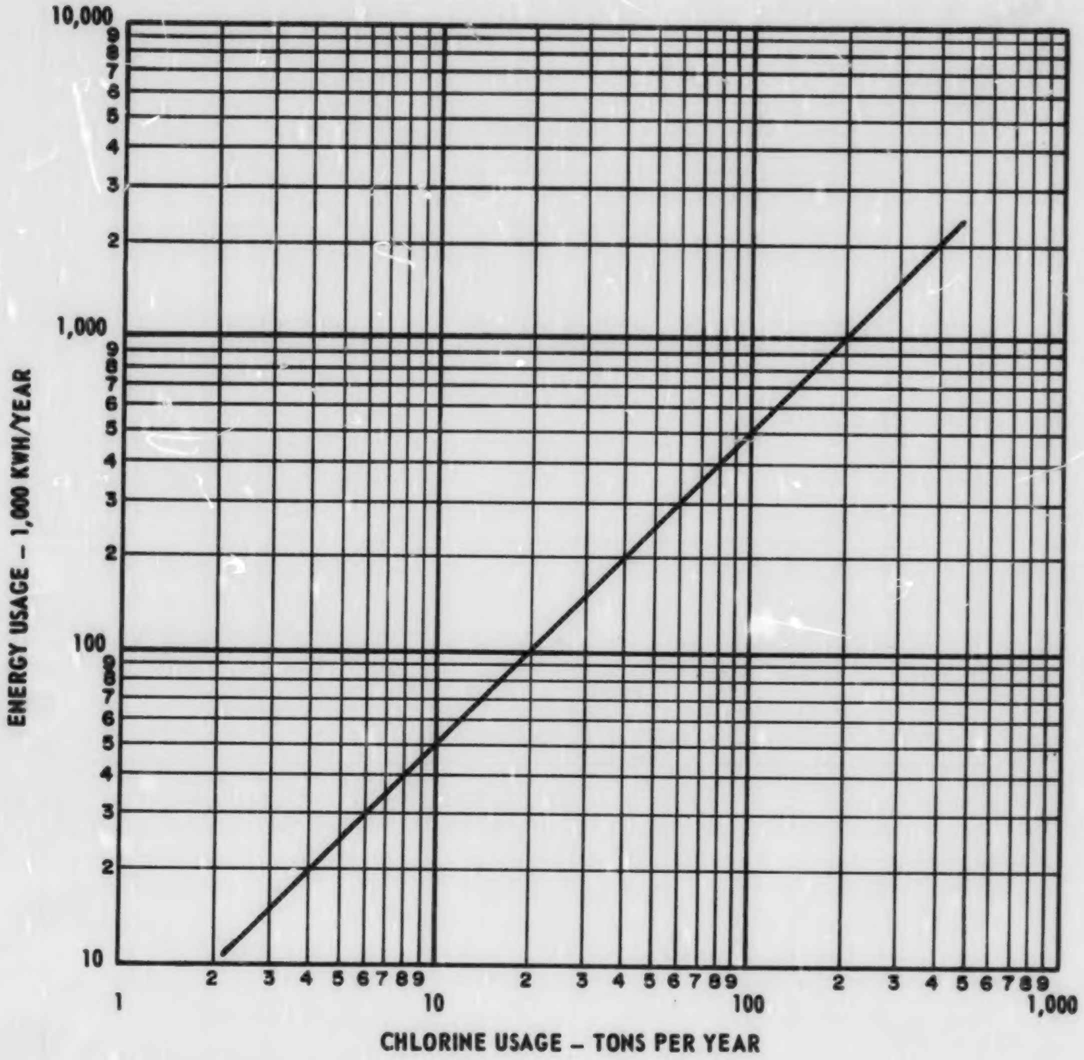


FIGURE 48 – HYPOCHLORITE GENERATION-POWER REQUIREMENTS

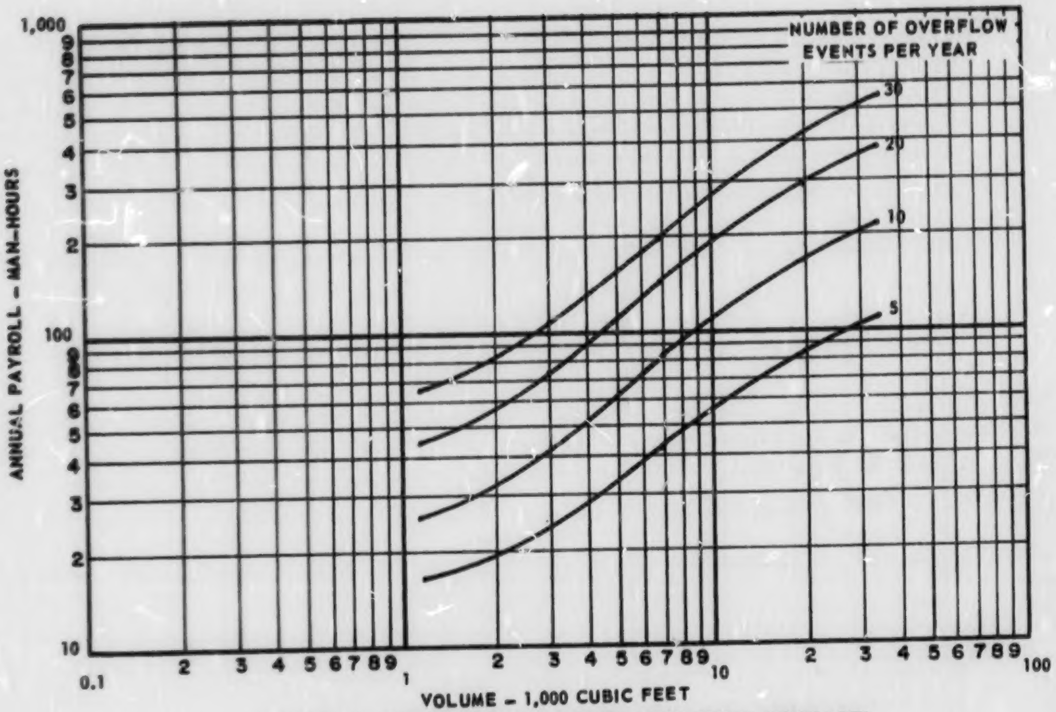


FIGURE 49– HIGH INTENSITY MIXING (CHLORINE CONTACT) MAN–HOUR REQUIREMENTS

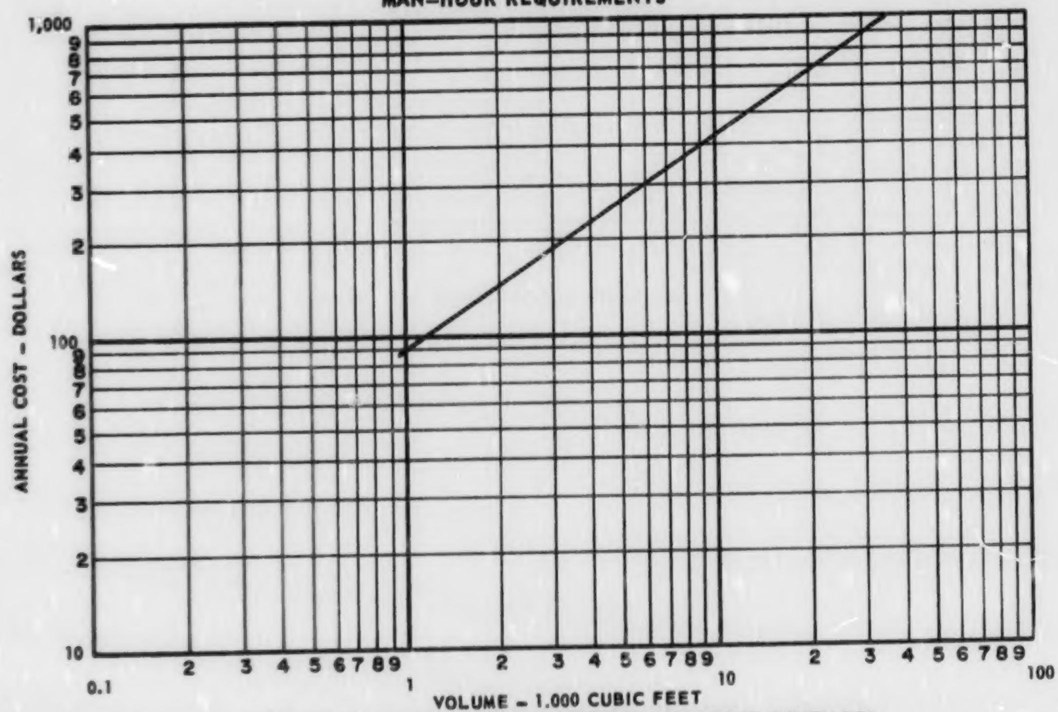


FIGURE 50–HIGH INTENSITY MIXING (CHLORINE CONTACT) MISCELLANEOUS SUPPLY COSTS

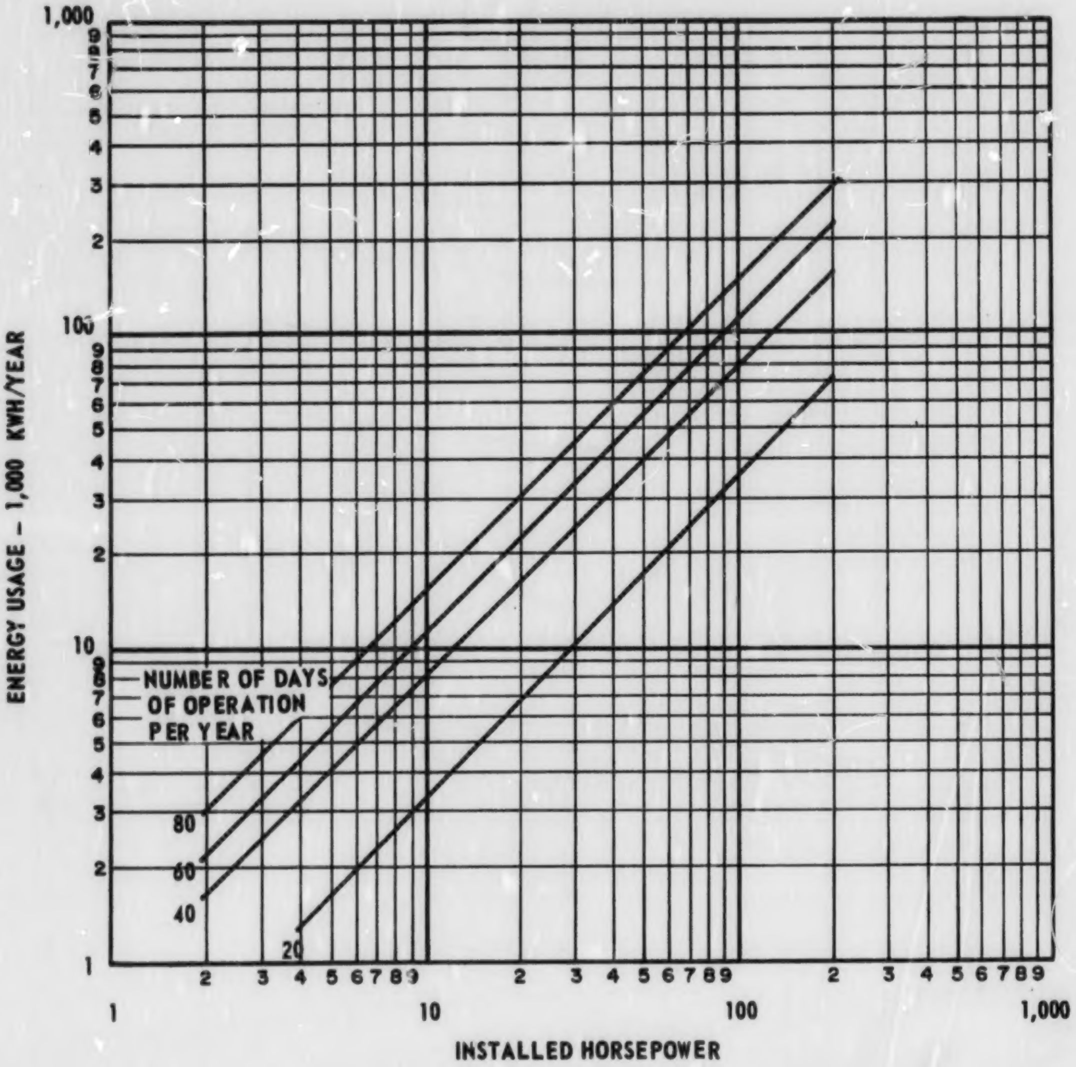


FIGURE 51 – HIGH INTENSITY MIXING (CHLORINE CONTACT) POWER REQUIREMENTS

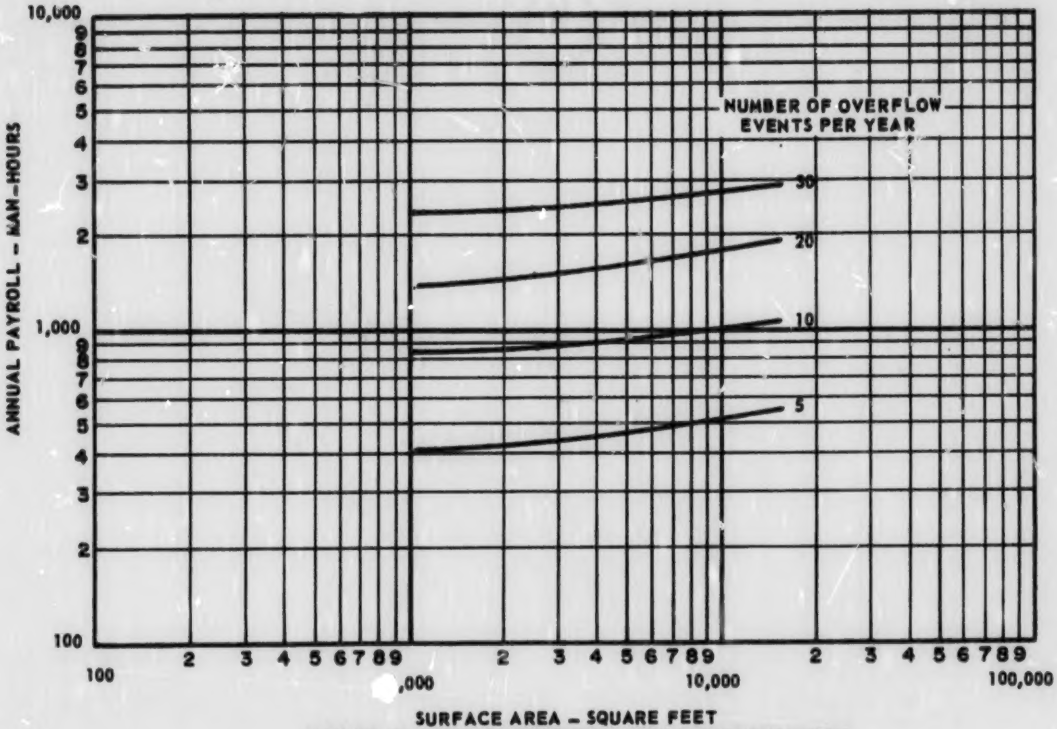


FIGURE 52 – FILTRATION-MAN-HOUR REQUIREMENTS

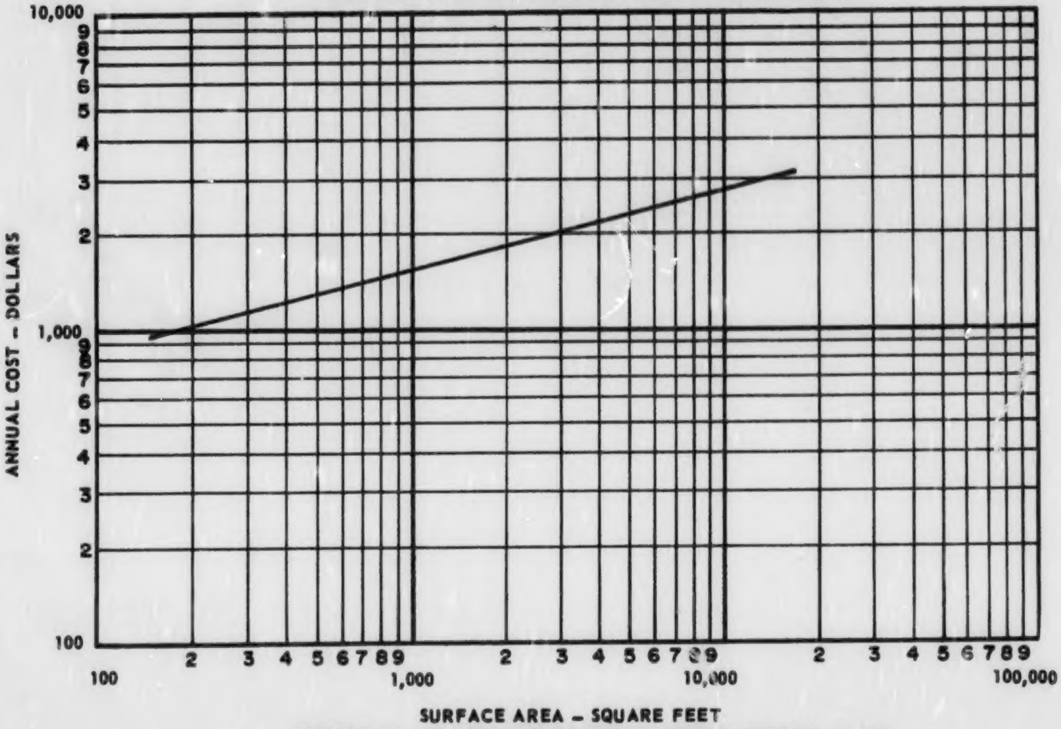


FIGURE 53 – FILTRATION-MISCELLANEOUS SUPPLY COSTS

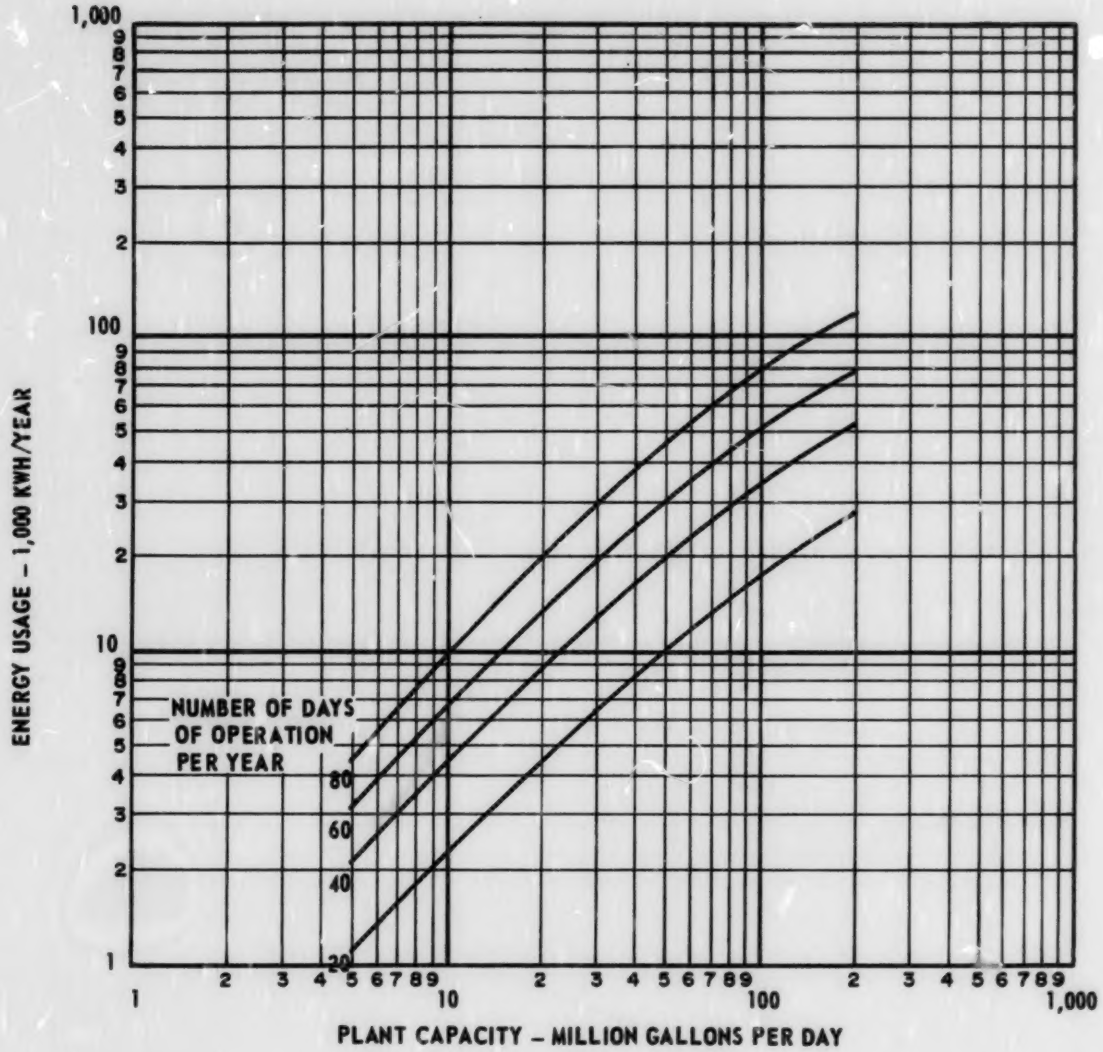


FIGURE 54– FILTRATION–POWER REQUIREMENTS

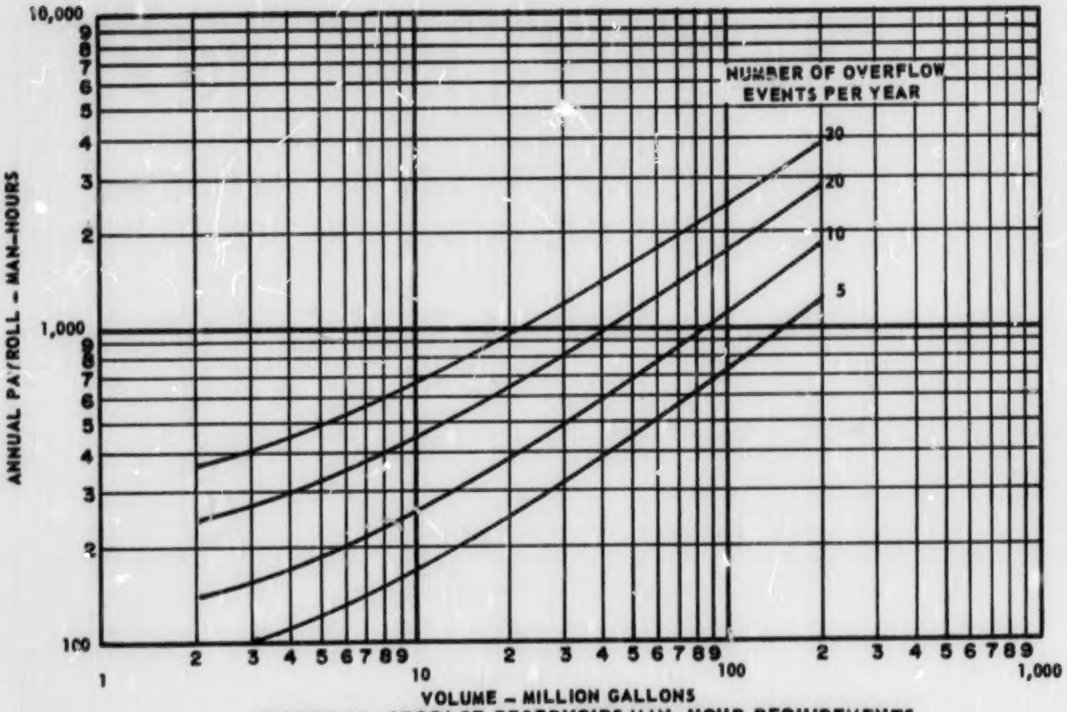


FIGURE 55- STORAGE RESERVOIRS-MAN-HOUR REQUIREMENTS

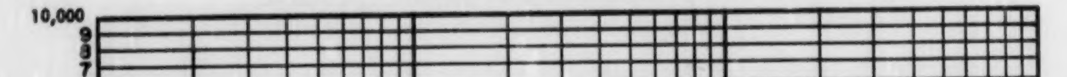


FIGURE 56- STORAGE RESERVOIRS-MISCELLANEOUS SUPPLY COSTS

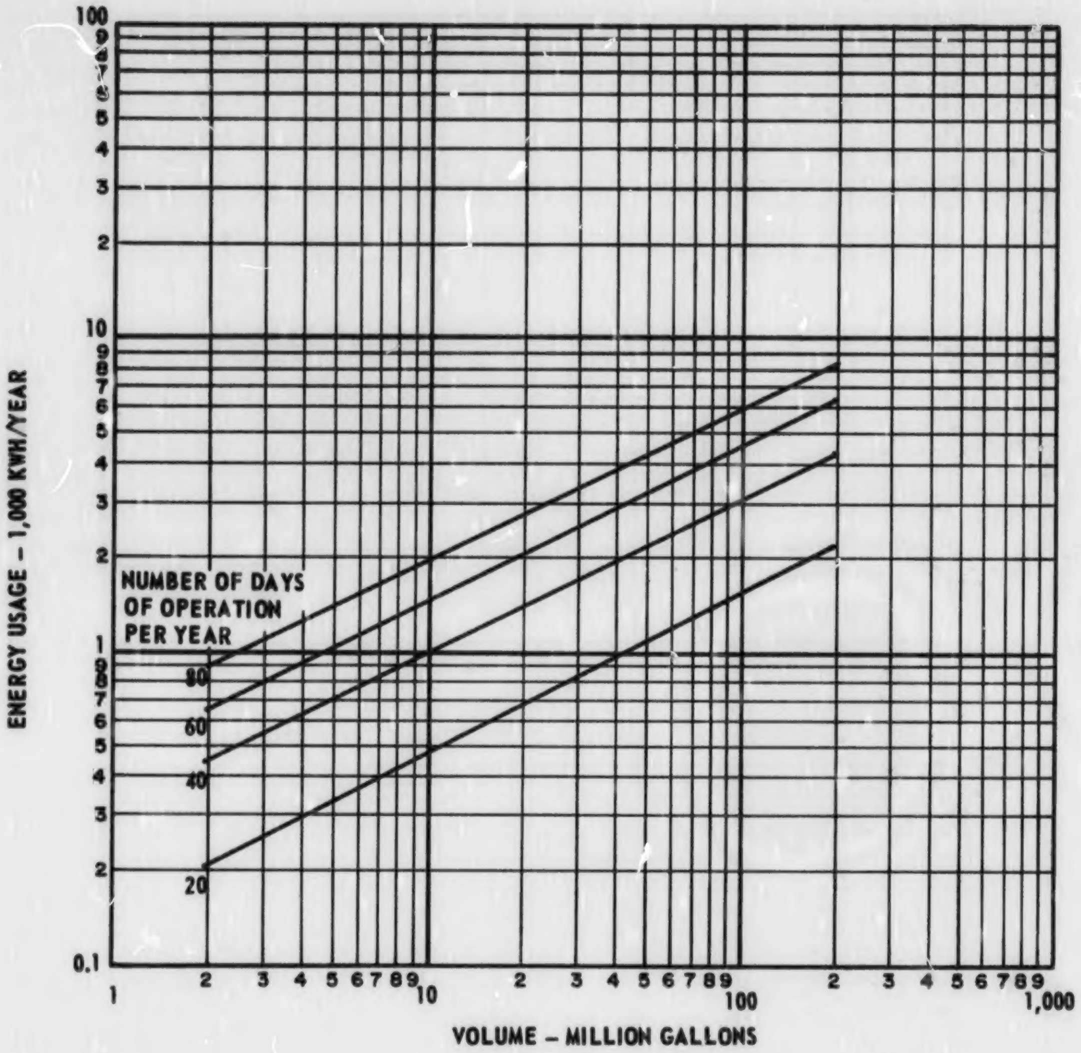


FIGURE 57– STORAGE RESERVOIRS-POWER REQUIREMENTS

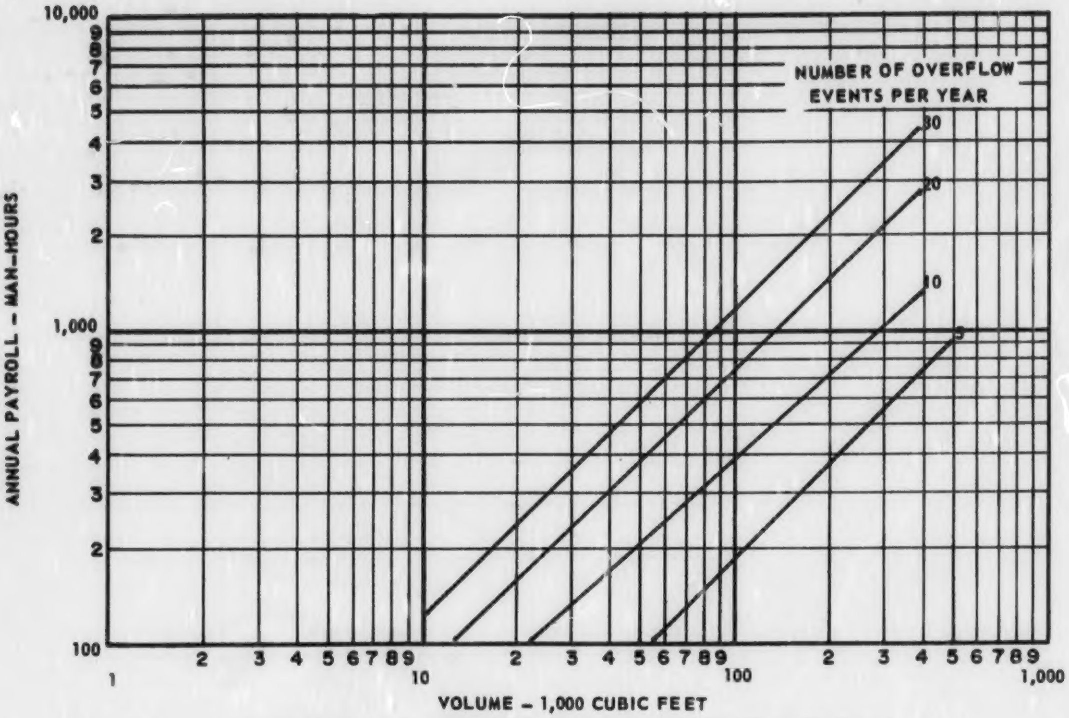


FIGURE 58 - FLOCCULATION BASINS-MAN-HOUR REQUIREMENTS

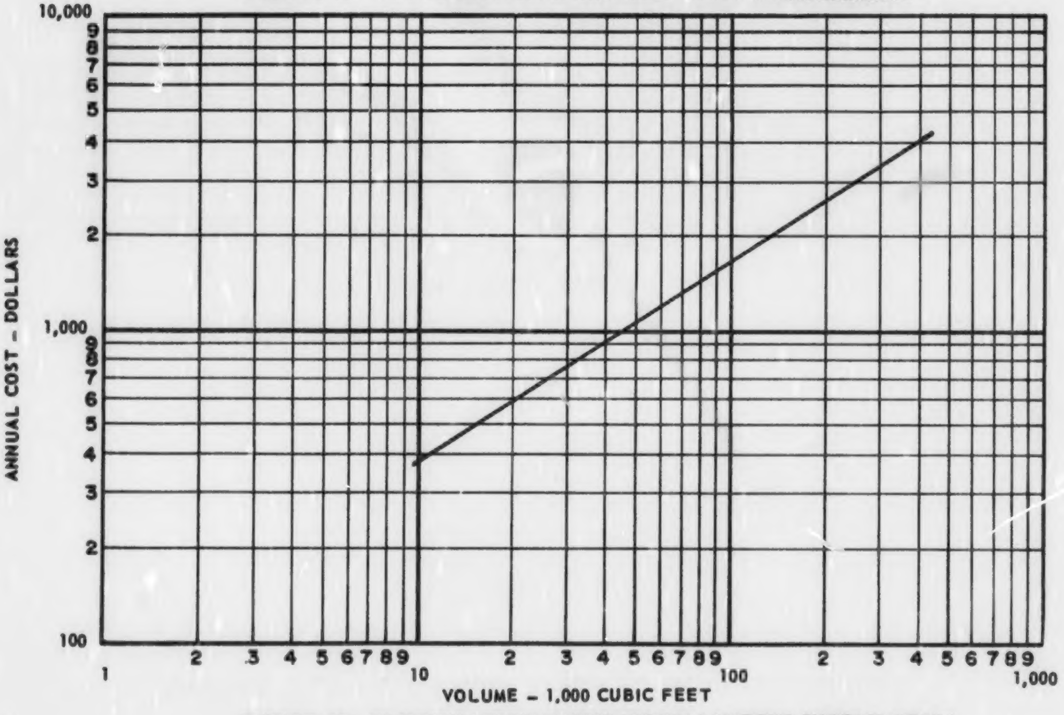


FIGURE 59 - FLOCCULATION BASINS-MISCELLANEOUS SUPPLY COSTS

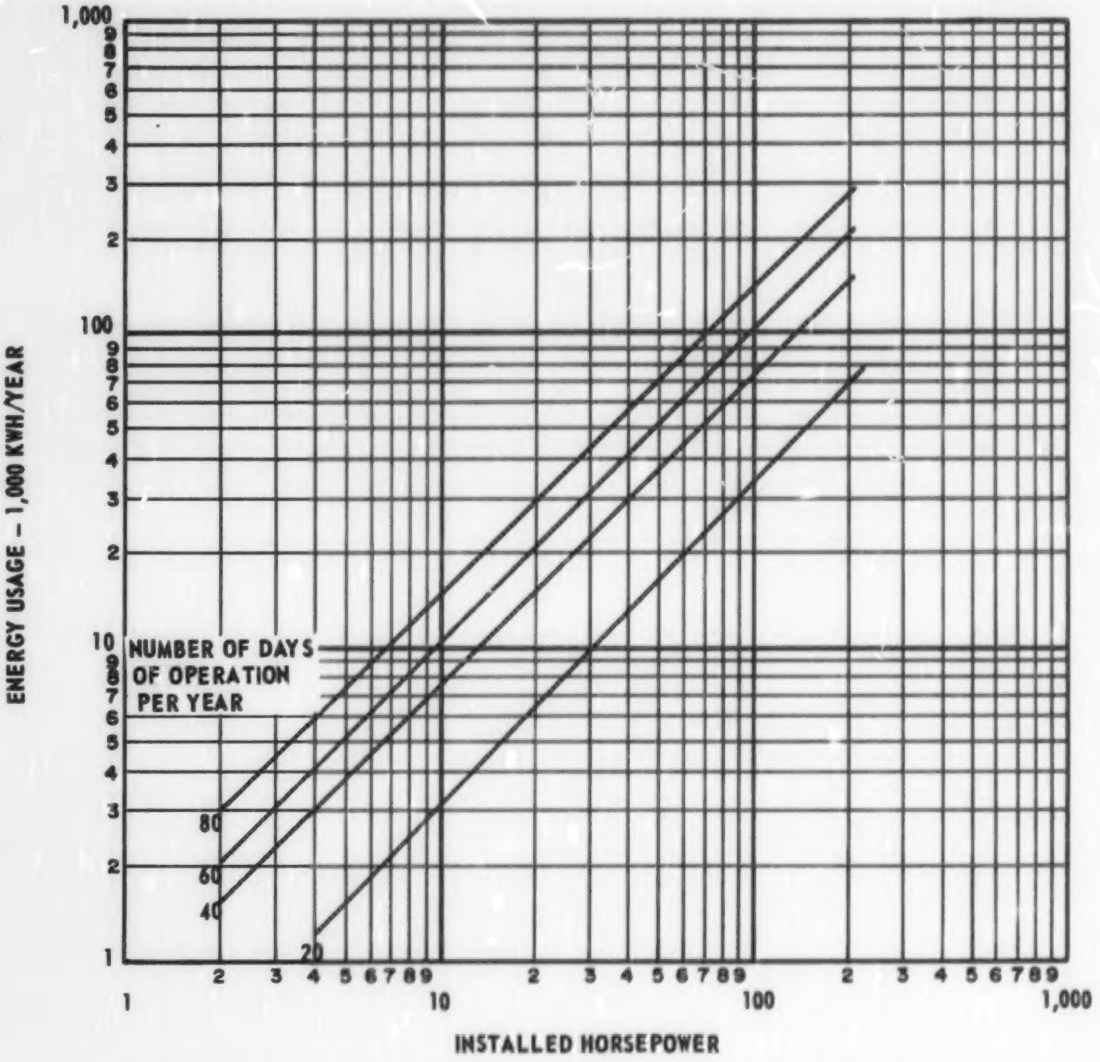


FIGURE 60 – FLOCCULATION BASIN-POWER REQUIREMENTS

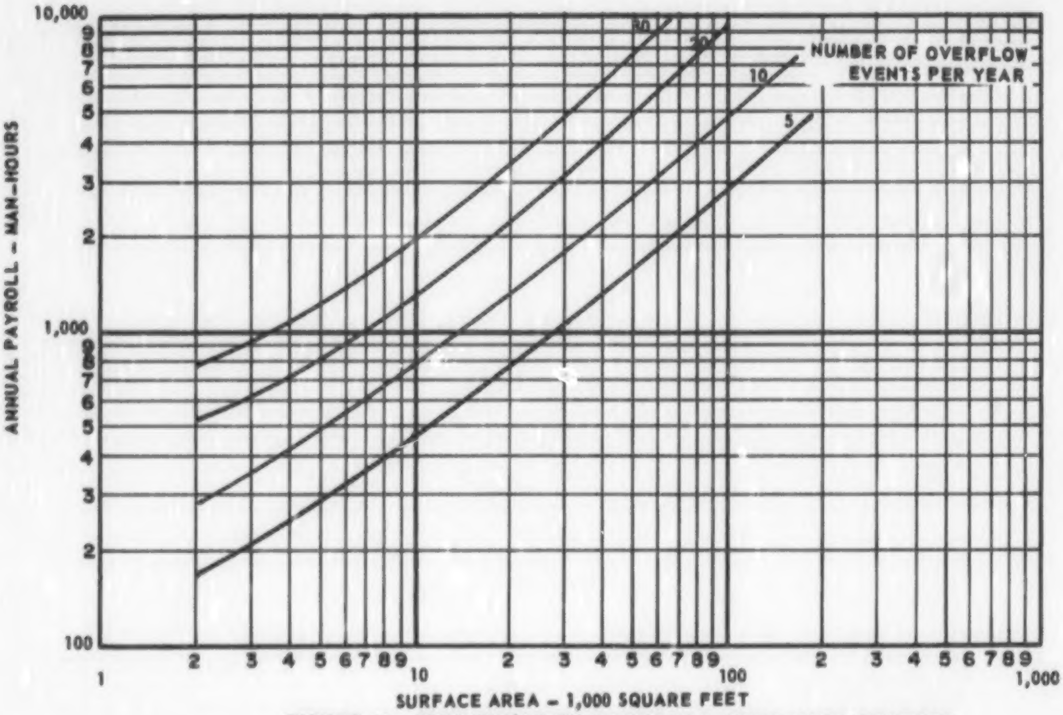


FIGURE 61- SEDIMENTATION BASINS-MAN-HOUR REQUIREMENTS

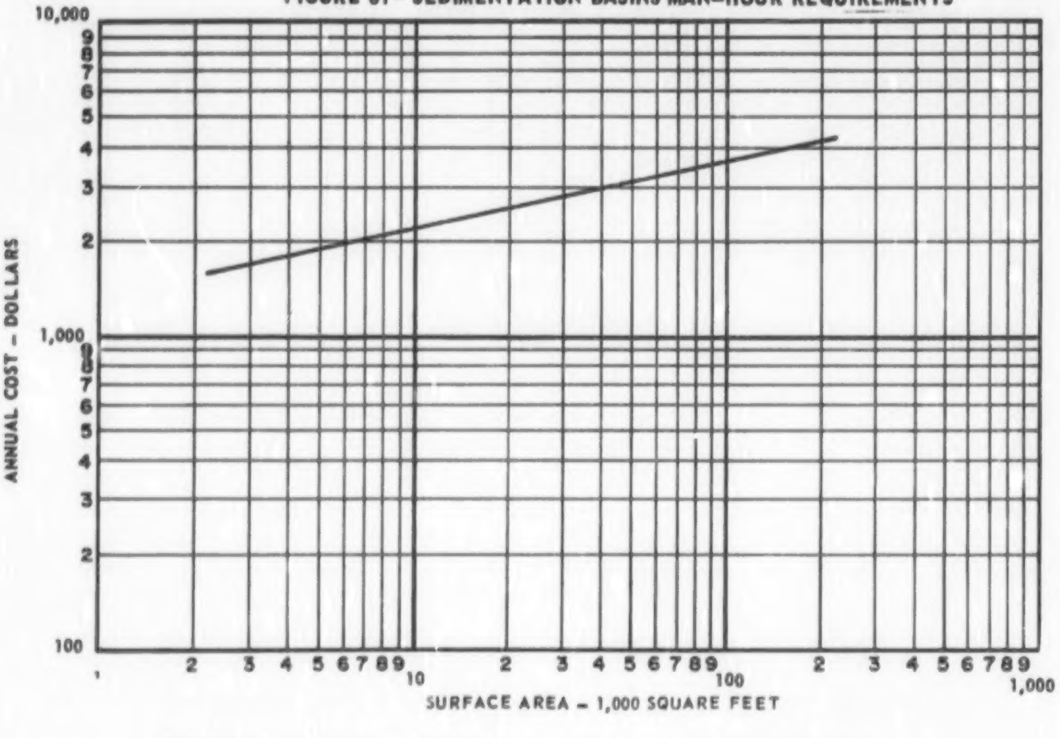


FIGURE 62- SEDIMENTATION BASINS-MISCELLANEOUS SUPPLY COSTS

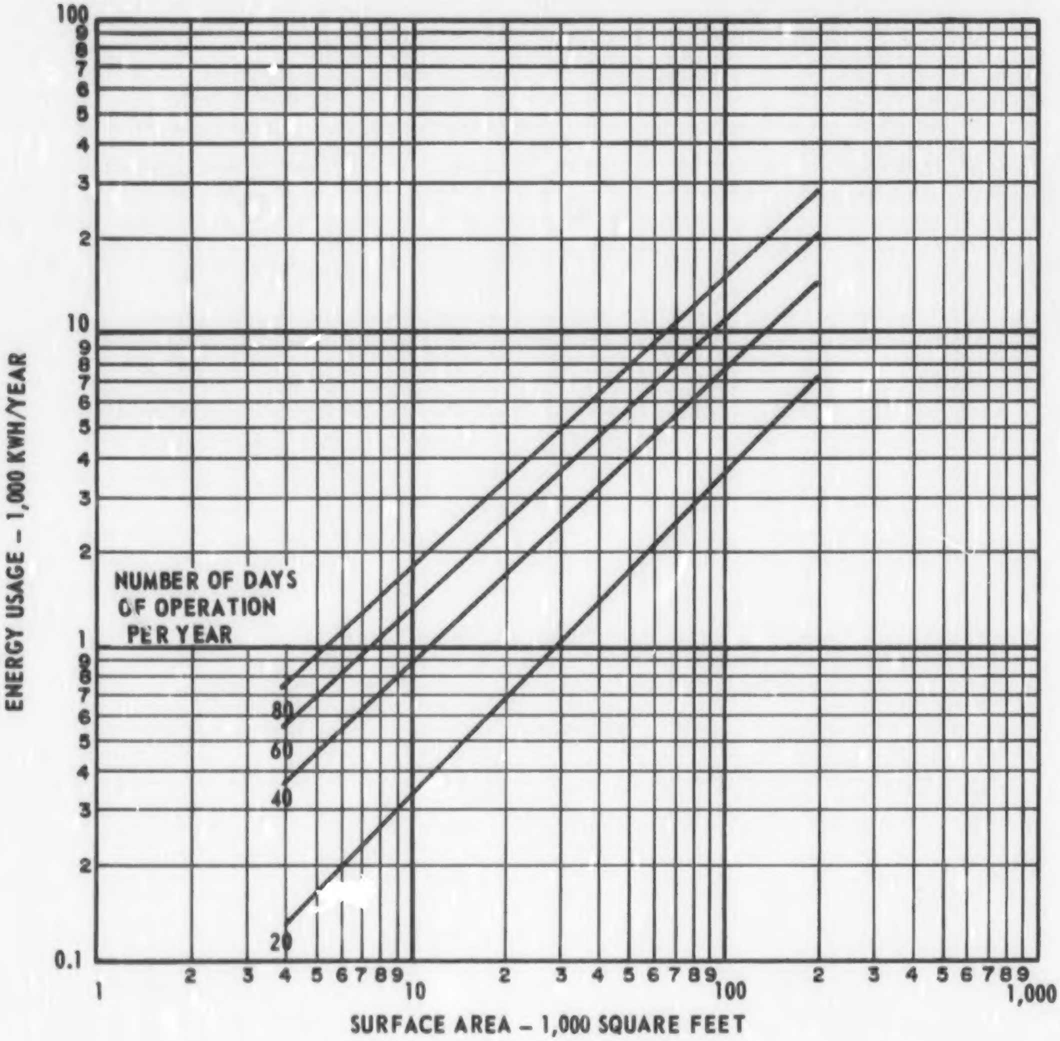


FIGURE 63 – SEDIMENTATION BASINS-POWER REQUIREMENTS

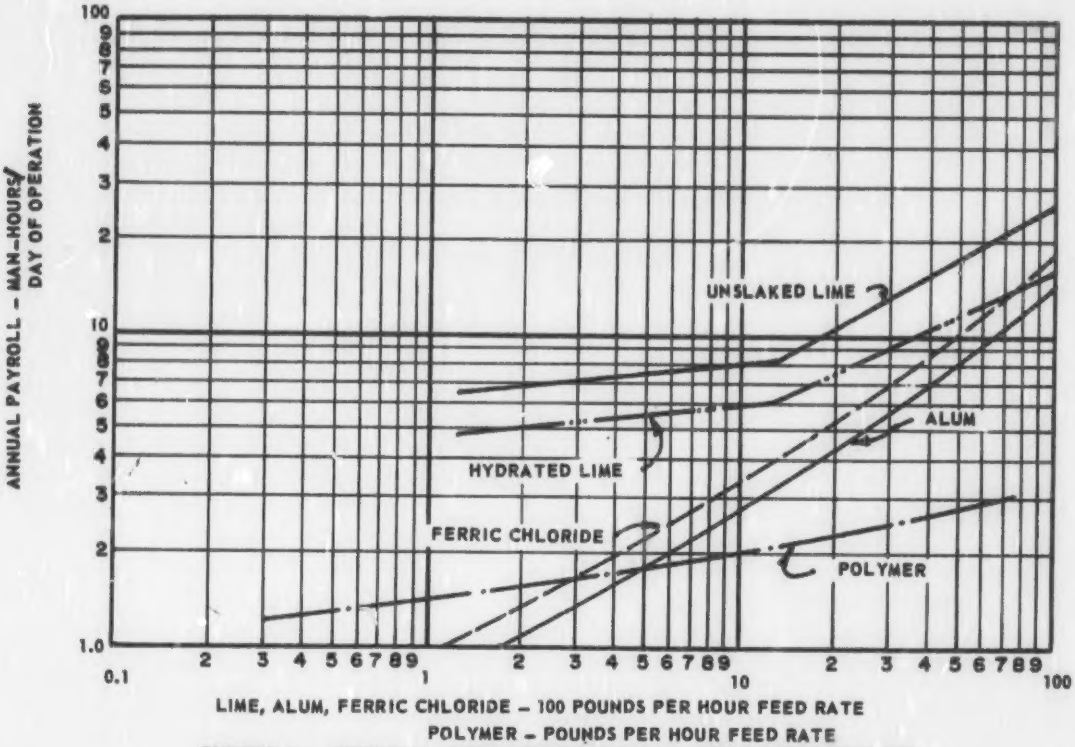


FIGURE 64– CHEMICAL FEED EQUIPMENT-MAN-HOUR REQUIREMENTS

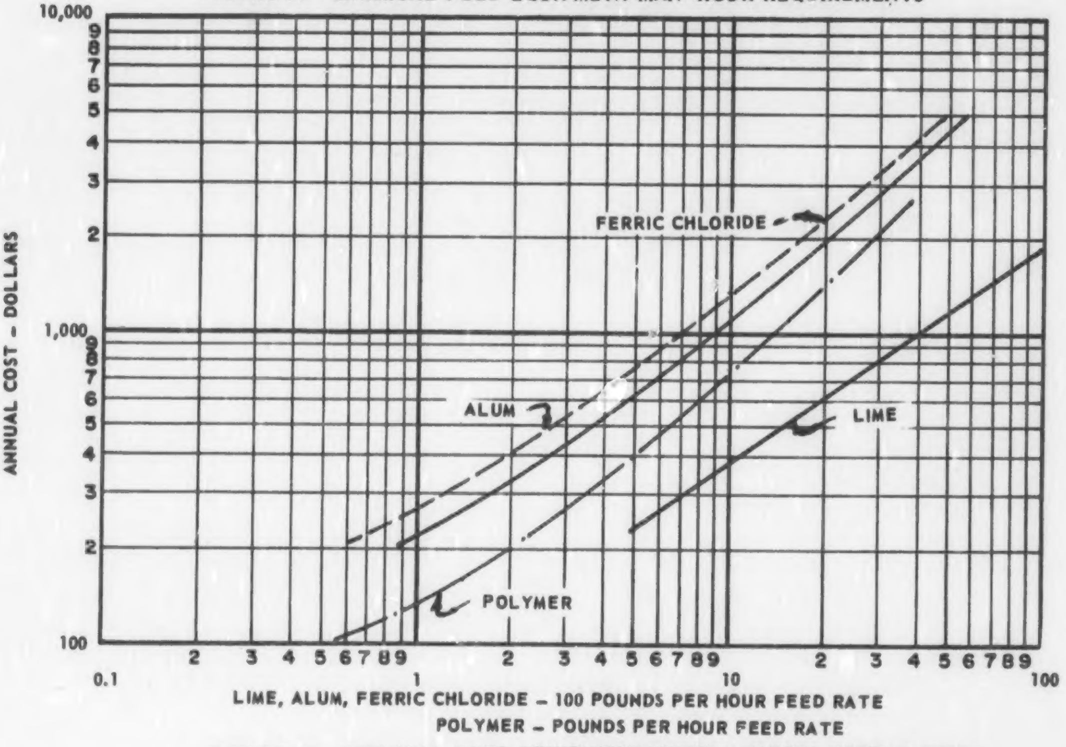


FIGURE 65–CHEMICAL FEED EQUIPMENT-MISCELLANEOUS SUPPLY COSTS

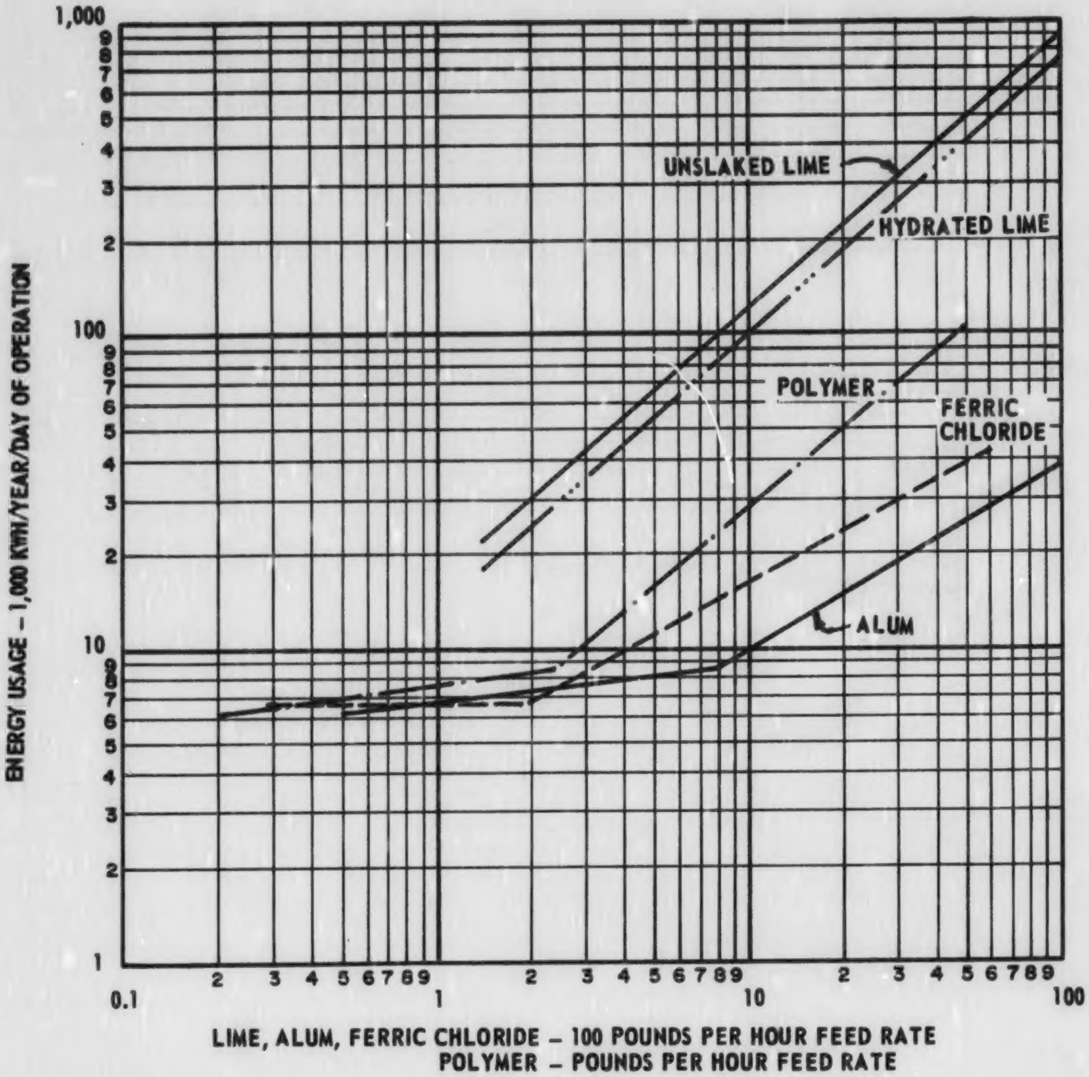


FIGURE 66– CHEMICAL FEED EQUIPMENT-POWER REQUIREMENTS

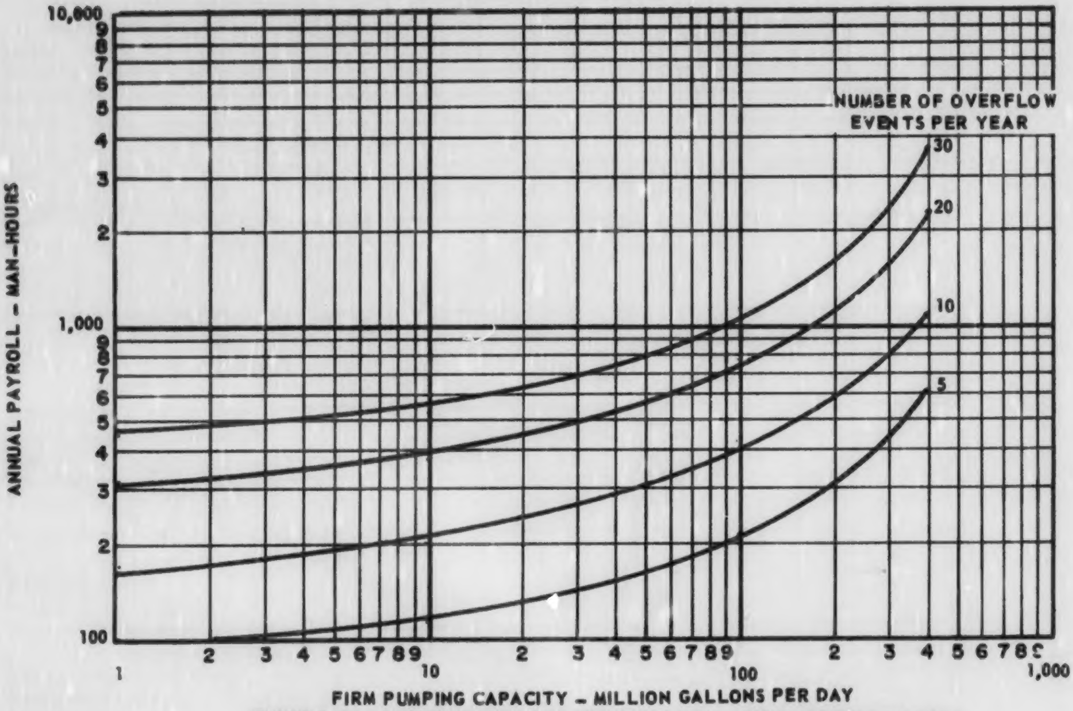


FIGURE 67 – RAW WASTEWATER PUMPING-MAN-HOUR REQUIREMENTS

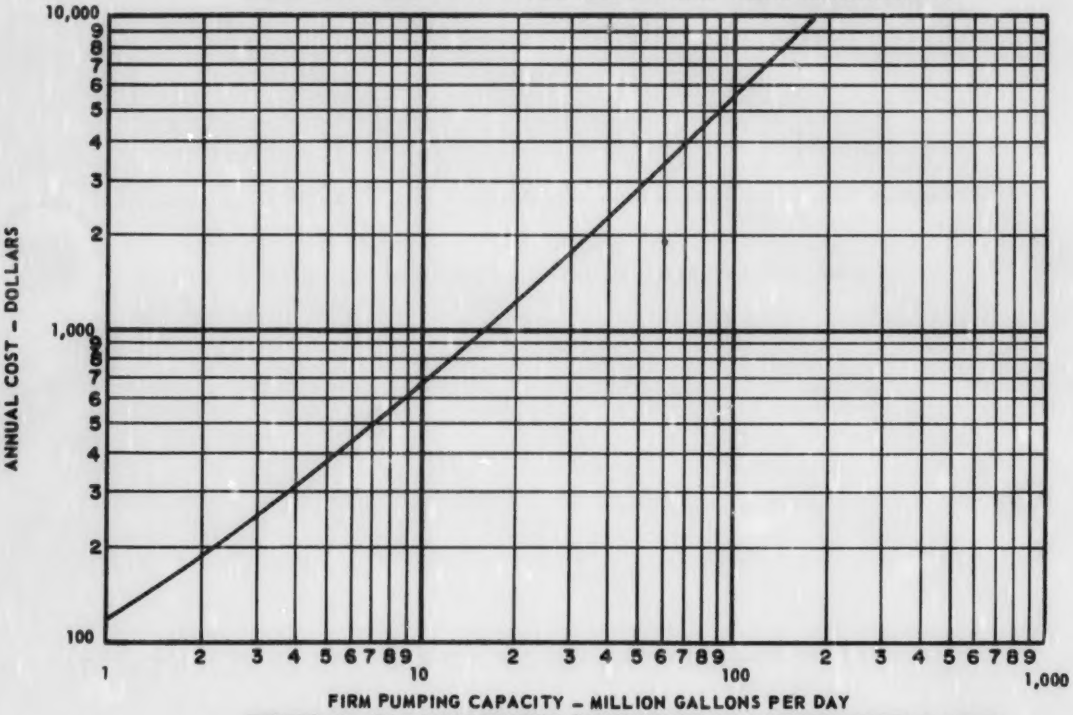


FIGURE 68– RAW WASTEWATER PUMPING-MISCELLANEOUS SUPPLY COSTS

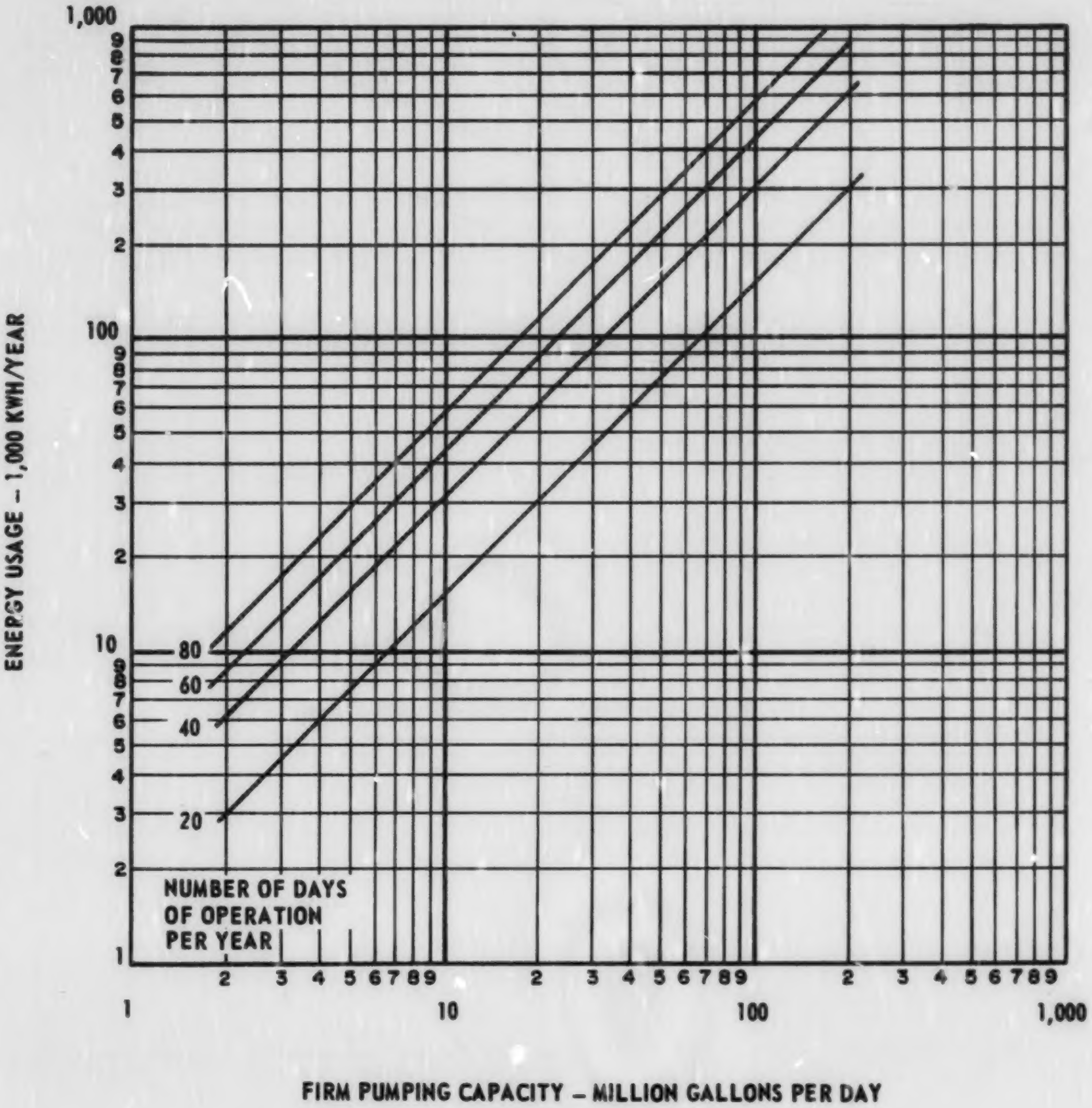


FIGURE 69 – RAW WASTEWATER PUMPING – POWER REQUIREMENTS

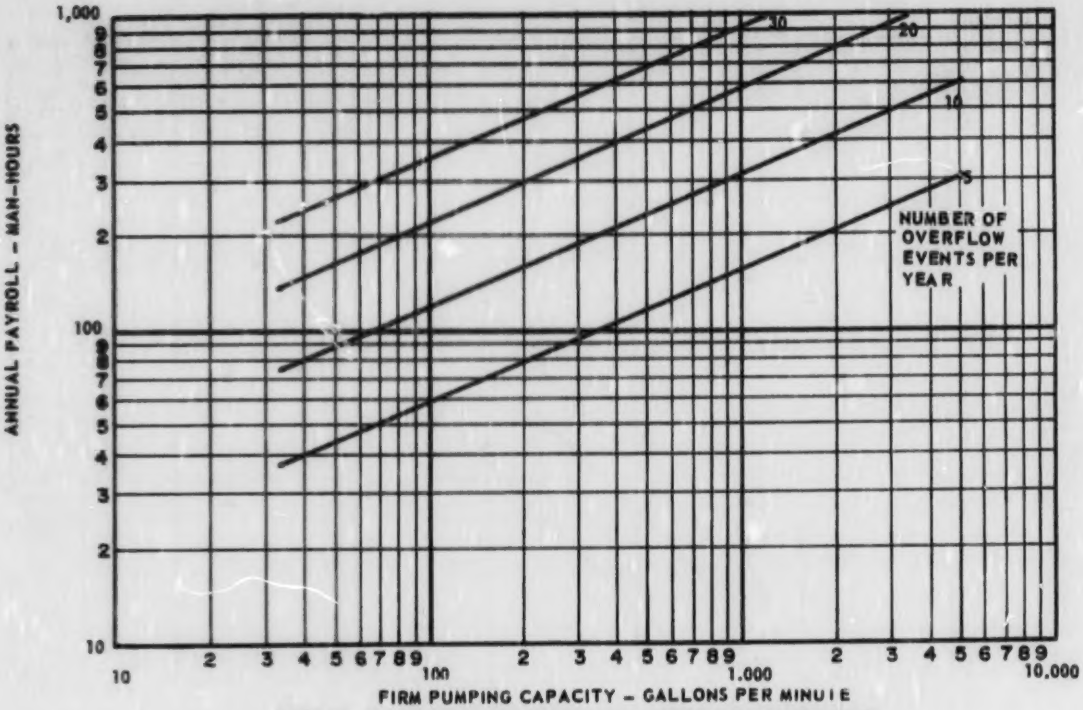


FIGURE 70 - SLUDGE PUMPING-MAN-HOUR REQUIREMENTS

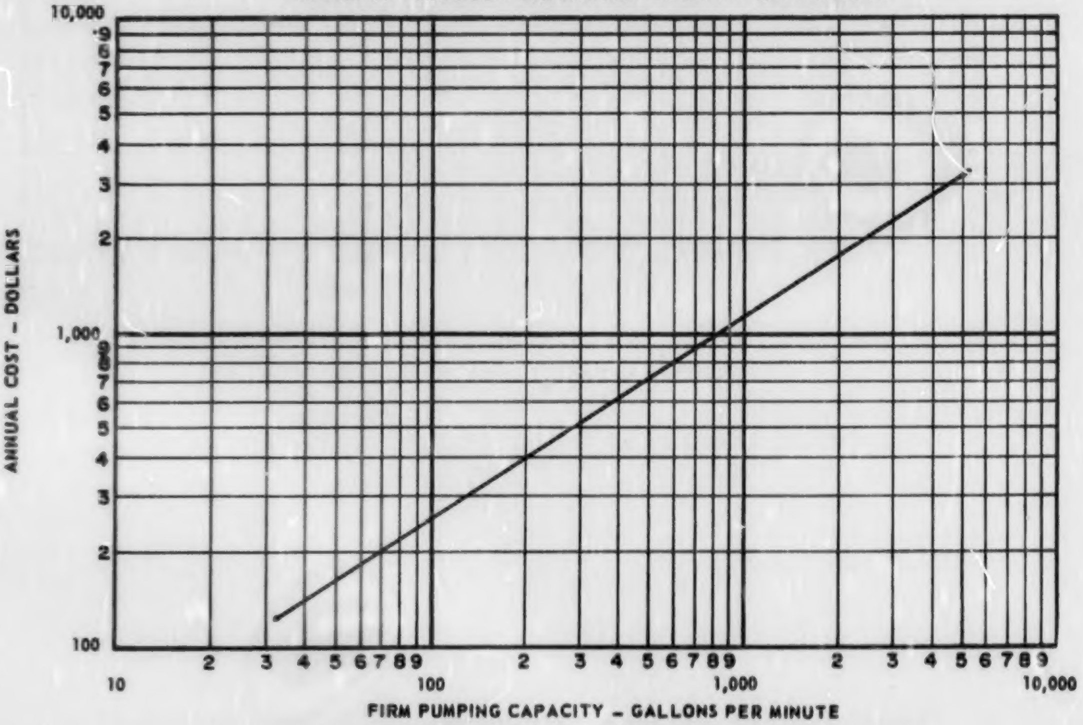


FIGURE 71 - SLUDGE PUMPING-MISCELLANEOUS SUPPLY COSTS

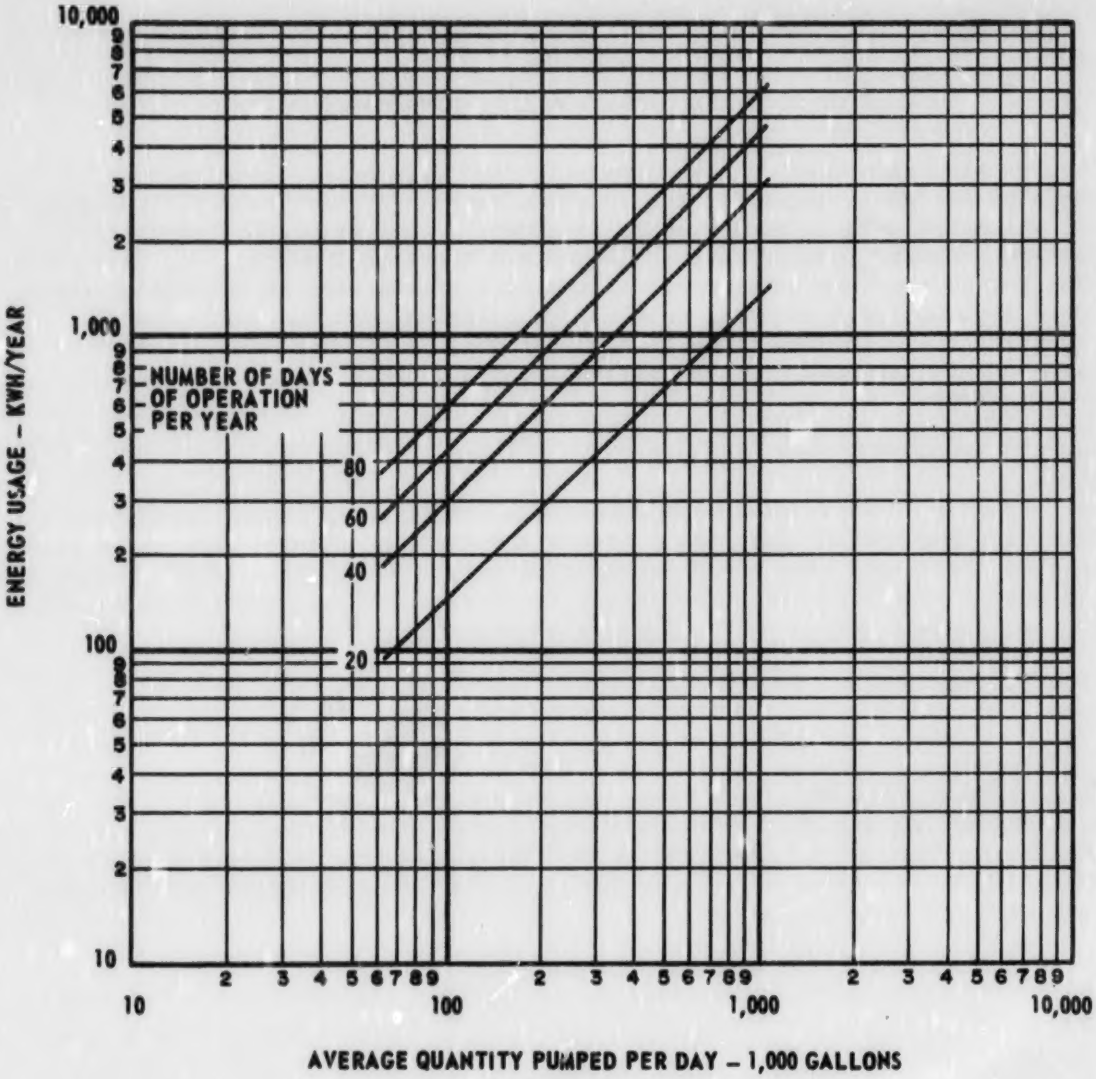


FIGURE 72 – SLUDGE PUMPING – POWER REQUIREMENTS

SECTION V

USE OF COST AND OPERATION AND MAINTENANCE DATA

The construction cost data and operation and maintenance requirements have been presented in detail in the previous section of this report. The form in which the data is presented is intended to be flexible by permitting several combinations of unit processes and functional units to be assembled. The format requires more effort on the part of the user in assembling cost data as compared to general cost curves relating cost to plant capacity. However, the more specific nature of this data and format is intended to increase the accuracy of the cost estimate and operation and maintenance requirements.

A. CONSTRUCTION COST DATA USAGE

1. Inflation - To derive a capital cost estimate for plant facilities, the user must first establish a time frame for the project. The costs presented herein are based upon costs of materials and labor as they existed in June, 1975. It will be necessary for the user to inflate the costs presented to that time specific for the subject project.

The information has been presented to permit inflating costs by use of general indices, such as the EPA Sewage Treatment Cost Index or the ENR Building Cost Index. In addition, the user may elect to review the more detailed cost components of each unit process and inflate the individual cost components using the Bureau of Labor Statistics (BLS) wholesale price indices for individual material items, and wage scales as published by the BLS, Richardson Engineering Services, Dodge Reports, or Means Cost Estimating Data. The more detailed cost inflation method is appropriate for variable inflation of cost components.

Construction cost data presented herein have been categorized into the following major groups shown with an appropriate BLS wholesale price index:

Category	Index Designation	Index Number	Mid 1975 Value
Mfg. Equipment	BLS General Purpose Mach. & Eqpt.	114	180.1
Concrete	BLS Concrete Ingredients	132	174.0
Reinforcing Steel	BLS Steel Mill Products	1.013	195.0
Labor	ENR Wage Index (Skilled Labor)	-	213*
Metal Pipes & Valves	BLS Valves and Fittings	114.901	187.4
Concrete Pipe	BLS Concrete Pipe	1.332	169.4
Miscellaneous Steel	BLS Steel Mill Products	1.013	195.0
Housing	Means Building Construction Cost Data - Offices	-	32.85

*Based on Kansas City, Missouri

Other categories have been used which are specific to a process function and the user will be required to refer to the unit costs presented in the attached appendix and obtain current unit costs from the estimating references previously mentioned.

The method used in inflating an estimate from the data presented herein to current costs is by the following:

$$\text{CURRENT COST ESTIMATE} = (\text{1975 COST ESTIMATE}) \times \frac{\text{INDEX VALUE CURRENT}}{\text{INDEX VALUE, 1975}}$$

To project costs into the future, a prediction of future index values is necessary. There is no certain method to predict future costs and a conservative inflation rate allowance is usually selected based on recent past performance of inflation.

2. Preparing Cost Estimates - The cost estimates presented herein are intended to represent average conditions and as such serve as guidelines. Local conditions affecting costs are very significant in cost estimating considerations and tend to invalidate the use of this data for some projects. Changes in regulations concerning construction practices and treatment plant equipment, technology, and reliability needs also affect costs. For example, the EPA mechanical and electrical requirements for wastewater treatment plants have caused a significant increase in construction costs, as have the OSHA regulations concerning construction practices.

The cost estimate for a plant facility is accomplished by listing the process functions included, selecting the appropriate cost from the data presented here, and adding allowances for site work, interest during construction, engineering services, and fiscal and administrative costs.

Because the individual components are variable, a specific format is not included in this presentation; however, an example is presented to assist the user in preparation of an estimate.

Nevertheless it is realized that the data presented herein will be used for specific projects as well as general planning purposes. For specific projects, the user should consider the basis for this cost data and become aware of construction costs in the local area.

Site work includes piping to and between process units, landscaping, drives, fencing, site clearing, and other items outside the boundary of plant functional or process units. Site work has been shown in the example to represent 15 percent of the subtotal of other construction costs. Based on 25 plants, the site work varies from 9 to 20 percent of the costs and is represented in this presentation as being 15 percent. This percentage should be reviewed for each project, and particularly for swirl overflow regulator/concentrators which have a large portion of cost associated with site work.

Example Cost Estimate

Functional Unit	Unit Parameter For Cost Estimate	Reference Figure No.	Cost Estimate
Raw Wastewater Pumping Station	100 mgd	25	$ 4,500,000
Flow Measurement Device	100 mgd	27	29,000
Rapid Mix	15,000 cu.ft. G = 300	17	130,000
Flocculation	200,000 cu.ft. G = 110	21	310,000
Air Flotation	25,000 sq. ft.	10	2,700,000
Chlorination	2,500 ppd	12	90,000
Chlorine Contact Basin	15,000 cu.ft. G = 100	17	62,000
Alum Feed	4,000 pph	23	690,000
Polymer Feed	30 pph	23	390,000
		Subtotal	$ 8,901,000
Site Work (15 percent of subtotal)			1,335,000
	Total Estimated Construction Cost		$10,236,000

Other Costs:

Engineering	Design	614,000
	Inspection	100,000
	Special Reports	50,000
Land	(6 acres @ 5,000 dollars)	30,000
Legal, Fiscal Administrative (2%)		205,000
Interest During Construction		1,040,000
	Total Estimated Project Cost	$12,275,000

Engineering services may be budgeted on the basis of cost curves presented by ASCE and an estimate of project construction duration and inspection requirements. Special reports such as environmental impact reports, operation and maintenance, reports and others should be included.

Land costs are highly variable ranging from 500 to several thousands of dollars per acre. Land acquisition problems may influence the type of process selected in urban areas. No guidelines are presented herein to estimate land costs or requirements.

Legal, fiscal, and administrative costs are related to project costs but will vary from one situation to another. Average costs may range from 3.5

percent of the project cost for small projects to 0.2 percent of the project costs for large projects.

Interest during construction is that cost paid on borrowed funds during the construction of the project. The borrowed funds are those paid to the contractor and consultants. The dispersement pattern of those funds and the duration of the loss of use of the money without the concommitant use of the facilities is the basis for determining the cost of interest during construction.

Estimates of other plant processes may be determined in a manner similar to that presented above.

B. OPERATION AND MAINTENANCE REQUIREMENTS DATA USAGE

The requirements for operation and maintenance of combined sewer overflow treatment facilities have been developed at a time where little precedence is available to judge the adequacy or normality of the data derived. For that reason the user is cautioned to assess the basis of the data presented and recognize that actual needs may vary considerably from data presented.

The format used in presenting operation and maintenance requirements is intended to be general in nature and independent of unit cost where practicable. Therefore, labor requirements presented are as man-hours/year and power requirements are presented as Kwh/year. Miscellaneous supplies and costs are presented as costs and must be inflated. It is suggested that a composite index such as the BLS wholesale price index may be used.

Chemical costs have not been presented and must be determined by calculating the chemical requirements and ascertaining unit costs from manufacturers.

The operation at combined sewer overflow treatment plants, being intermittent and the schedule unpredictable, requires that they be automated; most plants now in service are automated. The major time requirements are those required to clean the facilities after use.

Using the same example presented for the construction cost requirements, the following format may be used in assessing operating and maintenance requirements.

Example Operation & Maintenance Requirements

Plant Design Basis:

Capacity: 100 mgd
Average Flow/Year: 2,700 mg
Number Days Operation: 60
Number of Overflow Events: 20

Process Function	Process Parameter	Reference Fig. No's.	Labor Requirements (Manhour/Year)	Miscellaneous Supply Rqmts. (Dollars/Year)	Power Rqmts. (Kwh/Year)
Administration	100 mgd	28,29	180	680	-
Laboratory	(4 samples/ day)	30,31	520	1,300	-
Yard Maintenance	500,000 sq. ft.	32,33	3,300	2,700	-
Raw Wastewater Pumping Station	100 mgd	67,68,69	770	6,100	500,000
Rapid Mix	15,000 cu. ft., 80 HP	49,50,51	280	570	90,000
Flocculation	200,000 cu. ft., 100 HP	58,59,60	1,400	2,700	110,000
Air Flotation	25,000 sq. ft.	43,44,45	3,000	5,200	3,400,000
Chlorination	30 tons/yr.	64,65	690	1,800	-
Chlorine Contact Basins	15,000 cu. ft., 10 HP	49,50,51	280	570	11,000
Alum Feed	1,600 pph	64,65,66	252	1,300	780
Polymer Feed	15 pph	64,65,66	138	1,100	2,280
			10,810	24,020	4,114,060

Summary:

Labor	10,810 MH/YR @ $10/Hour =	$108,100
Misc. Supply	$24,020/Yr. =	24,020
Power	4,114,060 Kwh/Yr @ $0.02/Kwh =	82,281
Chemicals		
Alum	2700 mg x 50 mg/l = 560 Tons/Yr @ $70 =	39,200
Polymer	2700 mg x 1 mg/l = 22,500 lbs./Yr @ $0.50 =	11,250
TOTAL ANNUAL OPERATION & MAINTENANCE COST		$264,851/Year

APPENDIX A

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APPENDIX B

UNIT PRICES

The following unit prices have been derived from the several sources of cost data referenced in the text and include contractor's overhead and profit.

CONCRETE	MATERIAL	LABOR
Ready Mix Concrete	\$27/yard^3	\$ 9.00/yard^3
Walls to 8' high	-	9.00/yard^3
Walls to 12' high	-	10.50/yard^3
Walls to 16' high	-	12.00/yard^3
Walls to 20' high	-	14.00/yard^3
Walls over 20' high	-	16.00/yard^3
Reinforcing	\$0.40/lb	0.25/lb
Forms	0.66/square foot	1.90/sq. ft.
Walls to 8' high		1.90/ " "
Walls to 12' high		2.20/ " "
Walls to 16' high		2.50/ " "
Walls to 20' high		2.90/ " "
Walls over 20' high		3.50/ " "
Steel Pipe or Cast Iron Pipe	\$1,000/ton	\$1000/ton
Large Earth Work Quantities	-	1.00/yard^3
Reservoir Liners	\$0.35/square foot	0.15/sq. ft.
Equipment Installation		0.30 to 0.50 times purchase price
Equipment	Manufacturer's quote plus 15% overhead and profit for general contractor	
Housing	\$30 per square foot including materials and labor	
Concrete Pipe	\$2 per lineal foot per inch of pipe diameter	

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